101/55

R&D IN THE CONSTRUCTION INDUSTRY

HEARING

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

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SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

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CONTENTS

WITNESSES

Page

September 12, 1989:

Richard N. Wright, Director, Center for Building Technology, National Institute of Standards and Technology; Jesse A. Pfeiffer, Jr., General Manager, Construction Productivity Advancement Research Program, Army Corps of Engineers, Department of the Army; Ronald J. Morony, Director, Innovative Technology and Special Projects Division, U.S. Department of Housing and Urban Development; and David W. Cheney, Science Policy Research Division, CRS 3

John Eberhard, Head, Department of Architecture, Carnegie Mellon University, Pittsburg, Pa.; Timothy S. Killen, Director of Research, Bechtel Corporation; and Eric Balinski, Marketing Manager, Living Environment 179

R&D IN THE CONSTRUCTION INDUSTRY

TUESDAY, SEPTEMBER 12, 1989

House of Representatives,
Committee on Science, Space, and Technology
Subcommittee on Science, Research and Technology,
Washington, D.C.

The subcommittee met, pursuant to call, at 9:30 a.m., in Room 2318, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Mr. Walgren. The subcommittee will come to order.

Research and development in construction is potentially a very important topic for this subcommittee and for the Nation as a whole. It is hard to think of a more basic industry when you think about it. It's hard to think of an older industry or one a modern society is more dependent on. We spend $350 billion per year building roads and bridges and homes and schools and factories and all the other structures which have permitted us to live in a modern society.

Two facts about construction stand out. Construction has become more expensive and more and more remedial construction work is necessary. We have moved from an era where one parent with a good job could provide shelter for the family, to a day when two workers literally does not guarantee that they will be able to have the purchasing power to buy a home. The increasing problem of homelessness even among the employed shows that something is sadly wrong with the dream of making America a land of basic opportunity for everyone.

At the same time, we are barraged with news stories about the Nation's deteriorating infrastructure. This weekend CBS ran another story about the large cost of rebuilding New York City, and, of course, that's just the tip of an iceberg. Across the Nation, deferred maintenance is catching up with us in the form of crumbling roads and unsafe bridges and facilities that clearly need to be reconstructed.

On the other hand, this subcommittee each year hears of the miracles of materials research, how brilliant scientists at home and abroad are designing new materials which provide properties that simply were impossible in the past. We also have seen automation sweep the factory and the office and, in many ways, come into our homes as well. By the year 2000, we expect computers and robots and advanced communications will make life, both at home and at work, more productive, more efficient, and more economic.

Our goal today is to look at the contribution research and development can make towards solving the large problems of quality shelter construction for all our citizens, and the task of repairing and improving our basic infrastructure. We wonder if enough is being done and whether the Government has been enough of a partner in support of domestic construction industries. In the 25 years since HUD was created, we have poured tens of billions of dollars into trying to create affordable housing, but very little into the study of how automation or how new capabilities could make housing construction more affordable.

We have poured tens of billions of dollars into the actual construction of roads, but very little into the study and the push that we could give new technology and new materials to make those roads better or less expensive.

We have also noticed that Japan and countries of northern Europe spend quite a bit of effort and give quite a bit of thought to these questions, which raises the nagging question of whether our strongly competitive position in the construction industry today will be slipping and will erode as modern technology around the world is brought to bear in this area.

We appreciate being able to have a cross section of Government, industry and academic leaders in construction research and development with us today to comment and talk about this subject. We hope our discussions will enable us to have a broader understanding and encourage greater discussion of this subject in the Congress and in the public and in the private sector, to develop a better understanding of the contribution that construction research and development could make to improving our position in America and what the next steps necessary to take advantage of opportunities in this area might be.

So, with that, let me welcome our several panels. The first panel—and I would ask you to come forward—Dr. Richard Wright, the Director for the Center for Building Technology at the National Institute of Standards and Technology; Jesse Pfeiffer, General Manager for Civil Works Research and Development, with the Army Corps of Engineers; Ronald Morony, Director of Innovative Technology with the Department of Housing and Urban Development; and David Cheney, Science Policy Research Division with the Congressional Research Service.

We welcome you all to our discussions and express our appreciation for your being here and your putting together some thoughts for our record.

Why don't we go through the panel in the order in which I introduced you to the stenographer and to all of us here, so we'll start first with Dr. Wright.

STATEMENTS OF RICHARD N. WRIGHT, DIRECTOR, CENTER FOR BUILDING TECHNOLOGY, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY; JESSE A. PFEIFFER, JR., GENERAL MANAGER, CONSTRUCTION PRODUCTIVITY ADVANCEMENT RESEARCH PROGRAM, ARMY CORPS OF ENGINEERS, DEPARTMENT OF THE ARMY; RONALD J. MORONY, DIRECTOR, INNOVATIVE TECHNOLOGY AND SPECIAL PROJECTS DIVISION, U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT; AND DAVID W. CHENEY, SCIENCE POLICY RESEARCH DIVISION, CONGRESSIONAL RESEARCH SERVICE

Mr. **Wright**. Thank you, Mr. Chairman, Mrs. Morella, Mr. Campbell. We appreciate the opportunity to discuss the—

Mr. **Walgren**. One second, please. I'm sorry. I had gotten going when I was relatively alone here, and I see some friends have come. So why don't I turn to them and recognize them for any comments they might like to make at the outset.

Mrs. **Morella**. We could let you do this alone, Mr. Chairman.

I just want to associate myself with the very cogent remarks that you made with regard to the importance of knowing what the Federal role is in research and development in the construction industry. We all have concerns about our infrastructures and we want to know what innovations have been made and exactly where we are and what we should be doing. So I thank you, Mr. Chairman, for calling this important meeting.

I probably speak for Mr. Campbell when I say that if we do leave, it's because there are simultaneous meetings going on. Thank you.

Mr. **Walgren**. Thank you, Mrs. Morella.

The gentleman from California, Mr. Campbell.

Mr. **Campbell**. Mr. Chairman, I am of the view that you can't handle this on your own, but I'm very grateful for you holding these hearings. Thank you.

Mr. **Walgren**. It's good for you to be here.

[The prepared opening statement of Hon. Jerry Costello follows:]

OPENING STATEMENT

BY U.S. REP. JERRY COSTELLO, ILLINOIS
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
SEPTEMBER 12, 1989
"Research and Development in the Construction Industry"

Mr. Chairman, many of my constituents are workers in the construction industry, an industry which accounts for about eight percent of the Gross National Product. However, our market share is declining internationally, and the jobs for those workers and our national construction industry depends on a competitive role with other nations.

Much of this competitive situation depends on increased research and development funding in the construction industry. We have seen a corresponding decline in many other industries that have failed to boost research and development funding, such as steel, electronics and the automobile industries.

This hearing will be an opportunity to review several of the federal agencies that are involved in construction and to look at ways to enhance their roles in research and development. It is vital that we begin to coordinate these efforts to prevent a decline and loss of jobs in the construction industry.

Mr. Walgren. Any further opening comments? The gentleman from Alabama? All right. Well, we'll then proceed with Dr. Wright.

Mr. Wright. Thank you for the opportunity to discuss the importance of research and development in construction to the international competitiveness of all U.S. industry and the safety and quality of life of all U.S. citizens. With your permission, I will submit my written testimony for the record and summarize it briefly.

Mr. Walgren. Without objection.

Mr. Wright. High quality, cost effective constructed facilities are required for the competitiveness of all U.S. industries. In this statement, I will focus on technical bases for competitiveness in the U.S. construction industry, rather than the constructed-related research of the National Institute of Standards and Technology.

Competitiveness in construction has three dimensions: competitiveness with other opportunities for investments in the U.S. economy; competitiveness with foreign goods and services in the U.S. construction market; competitiveness with foreign goods and services in foreign construction markets.

Problems are evident. The U.S. construction industry is losing ground on each of these fronts. These problems are documented in my written testimony. Now I will outline an approach to solving them.

In an all-industry assessment of productivity, Edward Denison emphasized the importance for productivity of technological innovations brought to practice through capital investments. Technical leadership is considered by industry authorities to be essential to competitiveness in construction.

Recently, leading U.S. and foreign design and construction firms were surveyed to obtain their views of international leadership in construction technologies. Nineteen areas of construction technology were considered. The U.S. was assessed by the respondents to lead in just four, to be even in one, and to trail in 14. Other recent articles cite specific instances of foreign leadership in innovative materials, tunneling, underground piping, robotics and earthquake engineering. Our European Community and Pacific Rim competitors have strong interests in competition with the U.S. construction industry in international markets and in our domestic market. They have technical advantages to exploit.

U.S. construction research is very limited compared to other nations and industries. A recent study by the National Academy of Sciences indicates construction R&D is only 0.39 percent of construction value, and 82 percent of this is funded by the private sector. Private sector R&D for construction focuses on product development from which research investments can be recouped in the marketplace. According to a recent study by the Office of Technology Assessment, this research for 1985 had an upper limit of $1,088 million. This is about 0.33 of one percent of their sales. These efforts are much smaller than those of our European Community and Pacific Rim competitors. For instance, one percent of the gross income of Japanese design and construction firms is used by them for research.

Construction is a giant but disaggregated industry. Small enterprises predominate. There usually is a unique team—owner, designers, contractors, et cetera—on each construction project. Each participant may have several simultaneous projects. The team members for each project usually have not worked together before and will not again.

This disaggregated nature gives construction great flexibility for innovation. A small organization can master a new technology or produce a new product, and convince an owner, designer or general contractor to try the innovation on a particular project without having to break into a highly centralized, monolithic system.

So, considering these realities of the U.S. construction environment, how can the U.S. regain technical leadership in construction and lead in international competitiveness? The following approach is suggested as consistent with the natures of the U.S. and its construction industry. It involves feasible investments in improvements of construction technologies. It takes advantage of the flexibility and diversity of the disaggregated U.S. construction industry. It exploits U.S. leadership in information technologies for advanced computation and automation.

The approach is open systems for construction products and services. The term "system" denotes an entire constructed facility, such as a building, or an element of a constructed facility, such as its heating system, or a construction process, such as structural design. A system is closed if it requires the use of specific and restricted sets of components. No substitutions, such as a component from another manufacturer, can be made for individual components. A system is considered open if well defined requirements for the performance of each component permit appropriate substitutions for individual components.

Open systems for construction products and services meet the needs of users for constructed facilities that are useful, safe, and economical. An answer can consider alternative suppliers for components of the initial system, can mix manual and automated functions in a cost-effective manner, can modify the system to respond to unanticipated requirements, and can upgrade the system incrementally as technologies and needs evolve.

Open systems stimulate private sector innovation. An entrepreneur can find a market for an improved product or service without having to create a complete, vertically and horizontally integrated system. For instance, an improved excavating robot can be used on a construction site along with equipment from other manufacturers.

The disaggregated, flexible U.S. construction industry is capable of responding effectively if open systems for construction products and services provide incentives to innovations. For such open systems, the U.S. needs performance-based national and international standards and regulations for commerce in and use of construction products and services. It needs consistent national and international approval systems for innovative products and services, so these can get into the marketplace.

It needs to develop and exploit advanced construction technologies competitively by exploiting the national and international research knowledge and information technologies to develop advanced construction products and services, and the industry needs to apply improved construction products and services through marketing and education.

Collaborative efforts among private and public sector organizations in the U.S. construction community are required to meet these needs. With open systems for construction products and services, the U.S. then will obtain higher quality and lower costs to attract greater U.S. investments in construction, openness of the marketplace to stimulate innovation and product development in U.S. industry, and technical leadership for competitiveness with vertically and horizontally integrated but less flexible foreign rivals.

Thank you, Mr. Chairman. I will try to respond to any questions you or your colleagues may have for us.

[The prepared statement of Richard N. Wright follows:]

STATEMENT OF RICHARD N. WRIGHT, DIRECTOR
CENTER FOR BUILDING TECHNOLOGY
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

BEFORE THE
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
SEPTEMBER 12, 1989

1. INTRODUCTION

Mr. Chairman, Mr. Boehlert, and members of the Subcommittee, thank you for the opportunity to discuss the importance of research and development in construction to the international competitiveness of all U.S. industry and the safety and quality of life of all U.S. citizens.

In this statement, I will focus on technical bases for competitiveness in the U.S. construction industry, rather than the construction-related research of the National Institute of Standards and Technology (NIST). Activities from 1983-89 as chairman of the Programme Committee and president of the International Council for Building Research, Studies and Documentation (the international organization of building research organizations), from 1983 to date as chairman of the U.S. side of the U.S.-Japan Panel on Wind and Seismic Effects, and in 1989 as member of the Program Committee for the 6th International Symposium on Automation and Robotics in Construction have given me a direct view of construction research, development and practice, worldwide.

Competitiveness has three dimensions:

- Competitiveness with other opportunities for investments in the U.S. economy, and therefore, the ability of the U.S. built environment to support the Nation's productivity and quality of life.
- Competitiveness with foreign goods and services in the U.S. construction market.
- Competitiveness with foreign goods and services in foreign construction markets.

Problems are evident. The U.S. construction industry is losing ground on each of these fronts.

Development and maintenance of technical leadership is vital to U.S. competitiveness in construction. In this testimony, NIST suggests an approach for industry to achieve the development and application of technologies for competitiveness that is consistent with the dynamic, disaggregated nature of the U.S. construction industry, and the traditional roles of private sector and governmental organizations. Discussions in this hearing, and in other construction industry forums, may improve this approach, or identify a better strategy for achieving and maintaining the technical leadership in construction needed for competitiveness of all U.S. industries and quality of life and safety for our citizens.

2. COMPETITIVENESS OF THE U.S. CONSTRUCTION INDUSTRY

IMPORTANCE OF THE U.S. CONSTRUCTION INDUSTRY

Construction is one of the Nation's largest industries. In 1988 [1], new construction put in place amounted to $401 billion, 8.4% of the GNP, providing employment for 6.5 million persons. Constructed facilities shelter and support most human activities. Their quality affects the competitiveness of U.S. industry, and the safety and quality of life of the people. Moreover, the quality of construction strongly affects the wealth of the Nation; over five-eighths of the Nation's fixed reproducible wealth is invested in constructed facilities [2].

NATURE OF THE U.S. CONSTRUCTION INDUSTRY

Construction is a giant, but disaggregated, industry. Small enterprises predominate in construction. There usually is a unique team (owner, architect, structural engineer, general contractor, specialty contractors, etc.) for each construction project. Each participant may have several simultaneous projects. The team members for each project usually have not worked together before, and will not again.

This disaggregated structure allows the construction industry to adapt to large, rapid changes in the volume of construction work. This disaggregated nature also gives construction great flexibility for innovation. A small organization can master a new technology or produce a new product, and convince an owner, designer or general contractor to try the innovation on a particular project, without having to break into a highly centralized, monolithic system. However, interfaces with other products or practices, liability concerns and regulations are barriers to innovation.

Construction here is considered to include the whole life of the project: initial planning and programming, design, manufacturing and site construction, occupancy and maintenance, and renovation or removal. This whole life viewpoint is necessary to give realistic attention to values and costs of constructed facilities. For instance, for an office building, the annual operating cost, including salaries of occupants, roughly equals the initial construction cost. The primary value of the construction industry comes from the productivity of the occupants, which depends on the fitness to use of the building.

TRENDS IN COMPETITIVENESS IN CONSTRUCTION

In 1988, new construction put in place amounted to 8.4 percent of the gross national product, near the average for the decade and down from the 11.9 percent attained in 1966 [1]. In contrast, Japan's is about 16 percent of GNP [3]. The relatively low U.S. construction to GNP ratio largely reflects the slower growth of the U.S.'s overall economy to that of Japan.

The cause of the transfer of capital from construction to other investments may be that better returns have been available from other investments. I have seen some evidence that productivity has not seemed to keep pace in construction.

The U.S. construction industry is losing ground to foreign competitors in both the international and domestic markets. Data cited by the Department of Commerce [1] measure the losses. Awards to U.S. contractors in overseas markets declined by 60% from 1982 to 1987. Foreign-owned construction firms won $8.9 billion in U.S. construction contracts in 1987, 3.5 percent of all U.S. construction contracts that year and more than double the amount won in 1982. The 1981 $744 million trade surplus in construction materials became a $2.3 billion trade deficit in 1987.

A number of factors affect the international competitiveness of the U.S. construction industry. These include: availability of financing for projects, exchange rates, other nations' restrictions on foreign competition for domestic projects, anti-boycott and business practice laws limiting the ability of U.S. firms to operate in some foreign environments, and relatively higher U.S. wages. However, technical leadership generally is considered essential to competitiveness of the U.S. construction industry [1, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16]. For instance, from the Office of Technology Assessment study of international competition in service industries [14]:

> Taken together, advances in construction technology will, over the next two or three decades, lead to huge increases in productivity. Currently, however, it is foreign companies, not American, that have the lead in fields like tunneling, reinforced concrete construction, and some applications of new materials. Overseas firms - especially the Japanese - do much more research on basic construction processes.

In an all-industry assessment of productivity, Denison [17] emphasizes the importance for productivity of technological innovations brought to practice through capital investments.

Recently, Koehn [18] conducted and reported a survey of leading U.S. and foreign design and construction firms to obtain their views of international leadership in construction technologies. Nineteen areas of construction technology were considered; the U.S. was assessed by the respondents to lead in just four, be even in one and to trail in fourteen. Recent articles [19,20] cite specific instances of foreign leadership in innovative materials, tunneling, underground piping, robotics and earthquake engineering.

Even though the U.S. leads in the general areas of computer aided design (CAD), computer aided manufacturing (CAM), and their integration (CAD/CAM), industry observers [21] assess the Japanese to be leading in their integrated application to housing. (Housing is almost half of the total U.S. construction.) In Japan, a home buyer can sit with a salesperson at a computer terminal, in a matter of minutes design and price the home, which then is automatically scheduled for production by automated equipment. In the U.S. CAD systems are used for design and production of drawings and bills of materials, and computer-controlled machines produce components such as roof trusses and wall panels, but integrated CAD/CAM is not being used for housing design and production.

Construction research is very limited compared to other nations and industries. A recent study by the National Academy [6] indicates construction R&D is only 0.39 percent of construction value with 82 percent of it funded by the private sector. Private sector R&D for construction focuses on product development from which research investments can be recouped in the marketplace. According to a recent study by the Office of Technology Assessment [7], this research for 1985 had an upper limit of $1,088 million, 0.33 percent of sales. Most technology development work by design and construction firms is expensed to specific projects rather then reported as research and development [22], but these efforts are much smaller than the one percent of gross income reported by Japanese design-construction firms [3].

The European Community and the European Free Trade Association will permit free flow of construction products and services within Western Europe by 1992 [23]. This will be the world's richest single market of 355 million persons. European standards and codes will be used by the member countries for acceptance of products and services, and a European product approval system will allow products made, tested and approved in one European country to be used in all without further testing or approvals.

In all of this effort there has so far been little U.S. involvement or input. However, these actions may have profound impact on the U.S. The European standards and product approval system may be a major barrier to U.S. exports of construction products and services, and may influence international standards for other markets to the detriment of U.S. interests. In order to gain access to the European market and other foreign markets, for reciprocity the U.S. could benefit from comparable, nationally-recognized practices for acceptance of construction products and services [24,25]. Moreover, there may be a long-term effect on imports of construction products and services to the U.S. European firms successful in the larger European market will be well prepared to be active in the U.S. and the rest of the world.

Normal, steady progress of competitors relative to the U.S. construction industry is not the only threat to competitiveness. Losses in a sudden disaster also threaten U.S. competitiveness in all industries, including construction. The U.S. insurance industry has become aware of the threat a major earthquake poses to the viability of the insurance industry, and the viability of all other industries depending on the insurance industry for protection and capital. The insurance industry has established an Earthquake Project to study vulnerability to earthquakes and develop remedial measures.

A specific instance from a recent newsletter [26] gives dimension to the threat: a Richter magnitude 7.5 earthquake on the Newport Inglewood fault in Los Angeles County during working hours, is estimated to cause 17,000 deaths and $50 billion in insured property losses. There is about a 50 percent probability of such an earthquake, in one or more U.S. metropolitan areas, in the coming decade. An effective earthquake hazard reduction program is thus vital to the lives and property of our citizens and our national security.

APPROACH TO U.S. COMPETITIVENESS

How can the U.S. regain technical leadership in construction and lead in international competitiveness? This issue has received wide attention, including that of Congress [27] in considering national technical policy. The following approach is offered as consistent with the natures of the U.S. and its construction industry. It includes feasible and appropriate improvements of construction technologies. It takes advantage of the flexibility and diversity of the disaggregated U.S. construction industry. It exploits U.S. leadership in information technologies for advanced computation and automation. It fits the "Technology and Competitiveness" statement of the National Academy of Engineering [28] and the recommendations of the M.I.T. Commission on Industrial Productivity [29].

The key element of the approach is the concept of open systems for construction products and services. The term system here denotes an entire constructed facility, such as a building; an element of a constructed facility, such as its heating system; or a construction process, such as structural design. A system is considered closed if it requires the use of a specific and restricted set of components. No substitutions, such as a component from another manufacturer, can be made for individual components. A system is considered open if well defined requirements for the performance of each component permit appropriate substitutions for individual components.

Open systems for construction products and services meet the needs of users for constructed facilities that are useful, safe and economical initially and over the entire service life of the facility. An owner can:

- o consider alternative suppliers for components of the initial system,
- o mix manual and automated functions in a cost-effective manner,
- o modify the system to respond to unanticipated requirements or conditions,
- o upgrade the system incrementally as technologies and needs evolve.

Open systems stimulate private sector innovation. An entrepreneur can find a market for an improved product or service without having to create a complete, vertically and horizontally integrated, system. For instance, an improved thermostat can be used in existing temperature control systems, an improved excavating robot can be used on a construction site along with equipment from other manufacturers.

Competitiveness of the U.S. in general requires high quality, cost effective constructed facilities supporting all manufacturing and service industries. To meet these needs, financing must be available to construct such facilities, and the construction industry must respond with quality construction at competitive costs. The disaggregated, flexible U.S. construction industry is capable of responding effectively if open systems for construction products and services provide incentives to innovations. For such open systems, the U.S. needs:

- o Performance-based national and international standards and regulations for commerce in, and use of, construction products and services.
- o Consistent national and international approval systems for innovative products and services.

To develop and exploit advanced construction technologies competitively, the U.S. construction industry also needs:

- o To exploit international and national research knowledge and information technologies (advanced computation and automation) to develop advanced construction products and services.
- o To apply improved construction products and services through marketing and education .

3. TECHNOLOGICAL NEEDS FOR COMPETITIVENESS

SCOPE OF TECHNOLOGIES FOR CONSTRUCTION

The extensive scope of technologies affecting competitiveness in construction is evident in the requirements for performance of a constructed facility, and in the many activities of the many participants in the life cycle of a constructed facility. The constructed facility in service must be:

- o Productive (functional, reliable, maintainable, energy efficient, etc.)
- o Environmentally acceptable

- Safe (for occupants, neighbors, investors, etc.)

The whole process of construction (planning, design, manufacture, site construction, commissioning, facilities management, etc.) must itself be efficient and effective for the facility to be competitive. Construction technologies support competitiveness of the constructed facility and competitiveness throughout the whole construction process. Construction technologies include:

- information processing (e.g. computer aided design)

- equipment (e.g. excavators)

- products (e.g. roofing)

TECHNOLOGIES FOR COMPETITIVENESS

At the request of Congressman Sherwood Boehlert, who serves on the Committee on Science and Technology and the Committee on Public Works of the House of Representatives, Engineering News-Record, SUNY-Utica College of Technology, and NIST sponsored a Roundtable on Construction Technology for the 90's in May 1986. Twenty-five participants represented owners, designers, contractors, regulators, labor, manufacturers of construction products and equipment, educators and researchers. While a one-day meeting cannot produce a complete agenda for research and development, discussions identified critical technical issues for the international competitiveness of the construction industry [30]:

- Information interface technologies supporting the automatic exchange of information among all participants in a construction project, and conducive to open systems of computing hardware and software for the participants.

- Automated communications and control systems for constructed facilities (such as "smart houses" and "intelligent buildings") that are reliable, break down gracefully (such as not causing blackouts), and are open for partial upgrading and to innovations by small manufacturers.

- Low-risk test beds for innovations such as trials of novel materials and systems in construction programs of Federal agencies.

- Informing public policy makers, such as regulators, of the technical bases for sound public policy decisions.

- Learning from foreign research and development and applying results to U.S. practices.

The Roundtable called for collaborative efforts by the private sector, educational institutions and government to respond to these critical issues of construction technology.

TECHNOLOGY APPLICATION

Research alone will not provide for U.S. technical leadership and competitiveness in construction. Research is only one step in the process for obtaining technical leadership. Technical leadership occurs when the most productive technologies are used effectively in practice. Figure 1 illustrates the research application process leading to technology application.

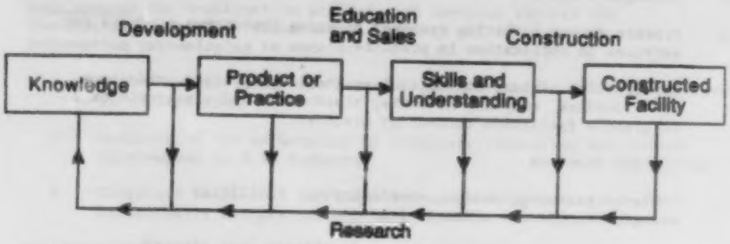
Development
Education and Sales
Construction
Knowledge
Product or Practice
Skills and Understanding
Constructed Facility
Research

Figure 1. Construction Research Application Process

Needs in the research application process include:

Research

- Includes studies of other fields, the built environment, and the research application process itself.
- Must keep up with advances in other areas of knowledge and other countries.
- Need both problem-focused work to improve practices and longer-term studies aimed at new knowledge.
- Need participation of users in problem-focused work.

Development

- Includes public efforts for development of improved practices and private development of commercial hardware and software.
- Must be a much larger effort than the research.
- Public support needed for development of public technologies (standards, measurement methods, etc.)
- Private sector investment essential to development of improved products and services.

Education and Sales

- Continuing education is needed to bring practitioners to the state of the art. Formal education, for long term relevance, will emphasize principles more than practices.
- Efforts needed to keep practitioners (designers, craftsmen, etc.) at the state of the art.
- Strengthen education of future professionals and technicians.
- Private sector marketing required to bring innovative products and services to application in practice.
- Exploitation of innovations such as knowledge systems, videotape and videodisk, computer networks, blackboards and electronic mail to greatly facilitate technology transfer.

Construction Practice

- Includes planning, design, commissioning, facilities management, etc. as areas of practice.
- Product approval system needed to facilitate marketing of beneficial innovations.
- Demonstrations may be needed to limit owners' and participants liabilities in trials of innovations.

4. SUMMARY AND RECOMMENDATIONS

TECHNOLOGICAL NEEDS FOR COMPETITIVENESS

Competitiveness of the U.S. construction industry is vital to the productivity of all U.S. industry and commerce and to the quality of life of all citizens. However, I believe that the U.S. construction industry is declining in its share of the gross national product, and losing in both domestic and international market share to foreign competitors. Development and maintenance of technical leadership is one, necessary requirement for competitiveness of the U.S. construction industry with:

- Other opportunities for investment in the U.S.,
- Foreign organizations in the U.S. market,
- Foreign organizations in international markets.

APPROACH FOR COMPETITIVENESS

For historical and practical reasons, the U.S. construction industry is diverse and disaggregated. Most organizations are small to medium sized enterprises, specialized in a particular facet of construction, and involved in a number of projects, usually with a unique team of collaborators on each project. The U.S. in general, and U.S. construction organizations in particular, possess international leadership in information technologies for advanced computation and automation.

Open systems for construction products and services exploit the flexibility of the U.S. construction industry and its leadership in information technologies to obtain:

- Higher quality and lower costs to attract greater U.S. investments in construction.
- Openness of the marketplace to stimulate innovation and product development in U.S. industry.
- Technical leadership for competitiveness with vertically and horizontally integrated, but less flexible, foreign rivals.

Collaborative efforts among private and public sector organizations in the U.S. construction community are required to develop the national standards, nationally-recognized product approval system, and other practices needed to achieve open systems for U.S. construction products and services. These also will provide the reciprocity required to open international markets to U.S. organizations. Investments in research and product development by private U.S. industry are needed to exploit the opportunities for competitiveness afforded by open systems for construction products and services.

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RICHARD N. WRIGHT

Date of Birth: May 17, 1932

Birthplace: Syracuse, New York

Education:

Syracuse University, B.S., Civil Engineering, 1953
Syracuse University, M.S., Civil Engineering, 1955
University of Illinois, Ph.D., Civil Engineering, 1962

Position:

Director, Center for Building Technology
National Engineering Laboratory
National Institute of Standards and Technology
(formerly National Bureau of Standards)

His professional experience includes: junior engineer with the Pennsylvania Railroad, 1953 to 1955; Instructor, assistant professor, associate professor and professor of civil engineering at the University of Illinois at Urbana from 1957 to 1974; and at the National Bureau of Standards, Chief of the Structures Section, Building Research Division 1971 to 1972, Deputy Director-Technical, Center for Building Technology, 1972 to 1973, and Director, Center for Building Technology 1974 to present.

The Center for Building Technology (CBT) is the national building research laboratory. It conducts laboratory, field and analytical research. It develops technologies to predict, measure and test the performance of building materials, components, systems and practices. It works cooperatively with other organizations, private and public, to improve building practices. CBT does not promulgate or enforce building standards or regulations, but its results are widely used in the building industry and adopted by private and governmental organizations that have standards and codes responsibilities. CBT programs include: computer integrated construction, structural safety, earthquake hazards reduction, building environment, and quality of building materials.

CBT has unique laboratory facilities and a staff of engineers and scientists of international reputation. Principal disciplines are structural, geotechnical, materials, mechanical and electrical engineering, physics, chemistry, architecture and behavioral sciences. Of the 100 professional staff members, 50 have earned doctoral degrees and 30 are registered engineers or architects. About 50 research associates sponsored by industry, visiting scholars from universities, and guest workers from foreign laboratories complement the professional staff.

Dr. Wright has published over 70 articles on building research, computer-integrated construction, formulation and expression of standards, performance of structures, structural design methods for earthquakes and other dynamic loads, flow and fracture in structural metals and mechanics of thin-walled beam structures.

He is Past President and Programme Committee Chairman of the International Council for Building Research, Studies and Documentation, Chairman of the Interagency Committee on Seismic Safety in Construction, U.S. Chairman of the U.S.-Japan Panel on Wind and Seismic Effects, fellow of the American Society of Civil Engineers, and member of the International Union of Testing and Research Laboratories for Materials and Structures, Earthquake Engineering Research Institute, National Society of Professional Engineers, Sigma Xi, Phi Kappa Phi, and Tau Beta Pi. He registered as a professional engineer in New York in 1958 and as a structural engineer in Illinois in 1974.

He received the Gold Medal Award of the Department of Commerce in 1982 for distinguished achievement in the Federal Service, and the Special Presidential Award of the Illuminating Engineering Society of North America in 1983 for contributions to the organization of the Lighting Research Institute. He was named Federal Engineer of the Year 1988 by the National Society of Professional Engineers, and selected for the Rank of Meritorious Executive by the President in 1988.

Mr. WALGREN. Thank you, Dr. Wright. Well, we'll go forward through the rest of the panel in the same order. We'll turn to Mr. Pfeiffer.

Mr. PFEIFFER. Thank you, Mr. Chairman, members of the subcommittee.

I am pleased to be here today to discuss how research and development can help to improve the productivity and overall competitiveness of the U.S. construction industry at home and overseas. With permission, I will submit my full written statement for the record and summarize in my remarks here.

Mr. WALGREN. Without objection.

Mr. PFEIFFER. Thank you.

Specifically, I will discuss initiatives which the Corps of Engineers has taken to assist the construction industry to regain preeminence in the construction business worldwide, and to help the Corps accomplish its mission more effectively.

Mr. Chairman, we agree with the committee's assessment that very little research and development is being accomplished within the construction industry. The engineering and construction industry, which in 1980 represented approximately 13 percent of our gross national product, is now down to about eight percent. Compared with other major industries, and using investment as a percentage of sales, the construction industry rates at the very bottom in R&D investment. The productivity of the construction industry, as measured by the Bureau of Labor Statistics, has declined by 15 to 20 percent from 1969 levels.

One way in which the situation can be arrested and the trend reversed is by capitalizing on existing R&D assets within the Federal Government. The Corps of Engineers has responded to this challenge in several ways, most notably the Construction Productivity Advancement Research program—CPAR, we call it. CPAR is designed to provide mutual benefit to both the construction industry and the American taxpayer. A cost-shared partnership formed by the Corps, the United States construction industry, academic institutions and other groups interested in construction productivity and competitiveness, CPAR was launched in 1988 to make maximum use of existing Corps research elements.

Cost sharing is one of the keys to the acceptance of this program. This provision spreads the risk. It also provides leverage for participating firms with a limited amount of funds to invest in R&D. Cost sharing also brings ownership to construction R&D that a fully funded Federal program would not. This ownership brings with it a desire to use the products of R&D.

In addition to having a direct favorable impact on the construction industry, CPAR provides cost savings and efficiency directly to the Corps mission programs.

CPAR has several features which distinguish it from other cooperative programs, such as the ability of the Corps to act on ideas received from industry. The program is based on construction industry bringing ideas to the Corps, which represents a major departure from the past. Previously, the industry had to respond to the Corps agenda, an arrangement that few in the private sector found appealing. Under CPAR, however, ideas, costs and benefits are shared.

Other CPAR differences include joint performance of the R&D, rapid transfer and application of R&D results through aggressive technology transfer and marketing actions, including exclusive licensing of the industry partner.

The two major criteria for project selection are the potential beneficial impact on the U.S. construction industry and on the Corps mission and program. Other criteria for evaluation are ease of adoption of results, anticipated chance of success of the R&D effort, project duration, R&D investment, and technology transfer potential.

As an initial concept, we have divided the CPAR program into four major areas. They are engineering and design improvements, improved construction site productivity, advanced materials, and then the last, the transfer of these products of R&D to the industry.

Some examples of the types of research possible in these four areas include—In the engineering and design improvement area, we are looking at expanding computer-aided design and engineering systems, materials selection systems, and the application of expert systems to a wide range of process improvements.

In the area of improved construction site productivity, we are considering new technologies in robotics and their applications at the construction site as part of the construction process. Also being considered are improved cold weather construction methods, construction management improvements, and materials handling innovations.

In the advanced materials area, we are looking at a range of new material technologies, including application of ceramics and advanced cementitious materials and adhesives and fasteners that provide better constructability, lower costs, increased durability, and longer useful life.

An area we are putting particular emphasis on is technology transfer management. In this area we'll be looking at innovative techniques for demonstrating, marketing and transferring technology to the ultimate user.

The response to the request for proposals for the fiscal year 1989 CPAR program was excellent. One hundred and forty-five proposals were submitted to the Corps. Our CPAR executive committee, which examined these proposals, selected 17 proposals. We expect to issue requests for proposals for the fiscal year 1990 CPAR program late this year.

Another initiative by the Corps is intended to help the construction industry compete effectively for work outside this country. The technical assistance program is the program I'm speaking of. This is a two-year demonstration program whose purpose is to provide nonexclusive technical assistance to U.S. firms that are competing for or have been awarded a contract for the planning, design or construction of a project outside the United States. Technical assistance means statistical or other studies and compilations, technical tests and evaluation, physical or numerical model studies, technical information, training activities, surveys, reports, documents and other similar service functions which the Corps is especially equipped or authorized to perform.

If the experience during the two-year demonstration program is beneficial to both the construction industry and the Corps, we will consider requesting authority from the Congress to make providing such assistance a permanent part of the Corps mission.

We believe that our experience in starting the CPAR program demonstrates the U.S. construction industry's interest in improving their abilities through research and development and application of advanced technology. I believe our experience also demonstrates a role that the Federal Government can play in helping the industry advance productivity and competitiveness by the Government being a leader, catalyst, and partner.

In closing, the Government can also provide leadership in several other ways. First, by continuing the high level of support for and emphasis on the difficult job of transferring technology developed in Federal laboratories to the construction industry. Second, by using Federal construction projects as the first application of advanced technologies. Third, by being a catalyst in helping to bring the very fragmented construction industry together, and fourth, by participating with and in various organizations which may be pursuing activities with the same motive.

I believe the CPAR program is showing that industry will respond to leadership and partnership. In addition, it shows that it is possible for more CPAR-like initiatives to be developed by other agencies, perhaps in specialty areas of the construction business, such as financing or codes and specification development.

Mr. Chairman, this concludes my remarks. I will be glad to respond to any questions you may have.

[The prepared statement of Jesse A. Pfeiffer, Jr. follows:]

DEPARTMENT OF THE ARMY
HEADQUARTERS, ARMY CORPS OF ENGINEERS

COMPLETE STATEMENT

OF

MR. JESSE A. PFEIFFER, JR., P.E.
GENERAL MANAGER, CONSTRUCTION PRODUCTIVITY
ADVANCEMENT RESEARCH (CPAR) PROGRAM

BEFORE THE SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

SEPTEMBER 12, 1989

INCREASING CONSTRUCTION PRODUCTIVITY THROUGH RESEARCH AND DEVELOPMENT

NOT TO BE RELEASED UNTIL APPROVED BY THE
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

DEPARTMENT OF THE ARMY
HEADQUARTERS, ARMY CORPS OF ENGINEERS
COMPLETE STATEMENT OF
MR. JESSE A. PFEIFFER, JR., P.E.
BEFORE THE
SCIENCE, RESEARCH AND TECHNOLOGY SUBCOMMITTEE
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

Mr. Chairman and Members of the Subcommittee, I am Jesse A. Pfeiffer, Jr., General Manager of the Construction Productivity Advancement Research Program in the Directorate of Research and Development of the Army Corps of Engineers.

I am pleased to be here today to discuss how research and development can help to improve the productivity and overall competitiveness, of the U. S. construction industry at home and overseas. Specifically, I will discuss initiatives which the Corps of Engineers has taken to assist the construction industry to regain preeminence in the construction business worldwide, and to help the Corps to accomplish its mission more effectively.

Mr. Chairman, we agree with the Committee's assessment that very little research and development is being accomplished within the construction industry. As a matter of fact, increasing costs of doing business has had a major negative impact on much of the nation's industrial base, and research and development (R&D) is among the areas hardest hit. The Congressional Budget Office estimates that since 1984 inflation adjusted R&D outlays in private U.S. firms have risen at an average annual rate of three percent, or about half the rate of gain of the preceding decade, and despite a significant increase in foreign competition, the portion of gross national product (GNP) devoted to R&D is lower today than 20 years ago. For the case of the U.S. construction industry, the numbers are even more dramatic.

The engineering and construction industry, which in 1980 represented approximately thirteen percent of our Gross National Product, is down now to about eight percent. Unknown to most people, this industry is the single largest industry in the United States. But compared with other major industries and using investment as a percentage of sales, the construction industry rates at the very bottom in R&D investment, with only 0.39 percent of sales being returned as an R&D investment. At the same time, the productivity in the construction industry, as measured by the Bureau of Labor Statistics, has declined by 15-20 percent from 1969 levels, with little indication of reversal of that trend.

One way in which the situation can be arrested and the trend reversed is by capitalizing on existing R&D assets within the Federal Government such that construction industry productivity can be increased and world-wide competitiveness restored.

The Corps of Engineers has responded to this challenge in several ways, most notably, the Construction Productivity Advancement Research Program (CPAR). CPAR is designed to provide mutual benefit to both the construction industry and American taxpayer. A cost-shared partnership formed by the Corps, the U.S. construction industry, academic institutions and other groups interested in construction productivity and competitiveness, CPAR was launched in 1988 to make maximum use of the Corps' existing research elements. The program builds on and benefits from the Corps $250 million per year research and development efforts, and the capabilities of its 1,100 engineers and scientists operating at six R&D facilities.

Cost-sharing is one of the keys to the acceptance of the program. This provision spreads the risk. It also provides leverage for participating firms with a limited amount of funds to invest in R&D. Cost-sharing also brings "ownership" to construction R&D that a fully funded Federal program would not. This "ownership" brings with it a desire to use the products of R&D.

In addition to having a direct favorable impact on the construction industry, CPAR provides cost savings and efficiency directly to the Corps mission programs. Technology advances resulting from CPAR will improve productivity and reduce the cost of Federal construction programs. As the cost of doing business is driven downward, new ideas and concepts will help improve productivity of the industry and the private and public sectors will share the benefits.

CPAR is being conducted within existing Corps authorities and missions and in compliance with the Federal Technology Transfer Act of 1986. However, the program has several features which distinguish it from other cooperative programs, such as the ability of the Corps to act on ideas received from the industry. These features were provided by certain provisions of the Water Resource Development Act of 1988.

The program is based on the construction industry bringing ideas to the Corps, which represents a major departure from the past. Previously, the industry had to respond to the Corps agenda, an arrangement that few in the private sector found appealing. Under CPAR, however, ideas, costs and benefits are shared.

Other CPAR differences include joint performance of the research and rapid transfer and application of R&D results through aggressive technology transfer/marketing actions, including exclusive licensing of the industry partner.

Under procedures established in the 1988 Water Resources Development Act, the Federal cost-sharing portion for research projects in the CPAR program is limited to 50 percent or less of the cost. The actual ratio for each proposal is based on benefits to the Corps and other factors.

The two major criteria for project selection are the potential beneficial impact on the U.S. construction industry and on the Corps mission and program. Other criteria for evaluation are ease of adoption of the results, anticipated chance of success for the R&D effort, project duration, R&D investment, and the technology transfer potential. Proposals are rated as high, medium or low potential for each criteria, and the cumulative results used to determine research priority.

A CPAR project is initiated by informal discussion between a potential partner, or group of partners, and a Corps R&D laboratory. If the laboratory sees potential in the idea being advanced, the potential partner is asked to submit a proposal providing detailed information.

Following discussions between the Corps laboratory and construction industry partner, a CPAR proposal summary is prepared and submitted to Corps headquarters for consideration under the program. An initial screening by the laboratory ensures that each submission meets the minimum criteria of being fully cost-shared and appropriate for the program. The proposals are then reviewed and recommendations for approval made by the CPAR Executive Committee, composed of senior-level Corps executives.

As an initial concept, we have divided the CPAR Program into four majors areas:

Engineering and Design Improvements
Improved Construction Site
Advanced Materials
Technology Transfer Management

Examples of some possible types of research in each of these areas are given below. These are only some of the possibilities and by no means are to be considered limiting.

In the Engineering and Design Improvement area, we are looking at expanding computer-aided design and engineering systems, materials selection systems, and the application of expert systems to a wide range of process improvements.

In the area of Improved Construction Site Productivity, we are considering new technologies in robotics and their applications at the construction site as part of the construction process. We know that the Japanese are undertaking major efforts at this time in robotic application at the construction site. Also being considered are improved cold weather construction methods, construction management improvements, and materials handling innovations.

In the Advanced Materials area, we are looking at a range of new material technologies, including application of ceramics and advanced cementitious materials and adhesives and fasteners that provide better constructability, lower costs, increased durability, and longer useful life.

An area we are putting particular emphasis on is Technology Transfer Management. If new technologies are not effectively introduced into application, the real benefits of research are never realized. In this area we will be looking at innovative techniques for demonstrating, marketing and transferring technology to the ultimate user. This may include the use of computerized information systems for communication of new technologies directly from the laboratory to the user community, as well as techniques using user review groups and other processes and concepts to validate technology and translate it into application.

The response to the request for proposals for the Fiscal Year 1989 CPAR Program was excellent. One hundred and forty-five proposals were submitted to the Corps laboratories. After evaluation, the laboratories submitted 56 proposals for consideration by the CPAR Executive Committee. The Committee selected 17 proposals. We expect to issue requests for proposals for the Fiscal Year 1990 CPAR Program late this year.

While CPAR will not solve all the problems confronting the construction industry today, it is an appropriate step in the right direction. Because CPAR is an innovative and highly cost effective program that will benefit both the Federal Government and the construction industry, it could also serve as a role model for other Government-industry partnerships.

Another initiative by the Corps is intended to help the construction industry compete effectively for work outside this country. The Technical Assistance Demonstration Program was authorized by Section 9 of the Water Resources Development Act of 1988. The purpose of the Program is to provide non-exclusive technical assistance to United States firms that are competing for or have been awarded a contract for the planning, design or construction of a project outside the United States. "Technical Assistance" means statistical and other studies and compilations, technical tests and evaluations, physical or numerical model studies, technical information, training activities, surveys, reports, documents and any other similar service functions which the Corps is especially equipped and authorized by law to perform. Firms requesting assistance must certify that such assistance is not otherwise reasonably and expeditiously available and agree to hold and save the United States free from damages due to the planning, design, construction, operation or maintenance of the project; and to provide, in advance, the funds to cover all costs of the assistance. Confidential information provided to the Corps by a United States firm will be protected. Assistance can be requested from any of the Corps R&D laboratories or divisions and districts, wherever the requisite expertise is available.

If the experience during the two-year demonstration program is beneficial to both the construction industry and the Corps, we will consider requesting authority from the Congress to make providing such assistance a permanent part of the Corps mission.

We believe that our experience in starting the CPAR Program demonstrates the U.S. construction industry's interest in improving their abilities through research and development and application of advanced technology. Over 145 firms, organizations and individuals indicated a willingness to commit their own resources to joint R&D by making proposals. I believe our experience also demonstrates a role that the Federal Government can play in helping the industry advance productivity and competitiveness, by being a leader, catalyst, and partner.

The Government can provide leadership in several ways:

1. By continuing the high level support for and an emphasis on the difficult job of transferring technology developed in Federal laboratories to the construction industry, being pursued under the Technology Transfer Act of 1986.

2. By using Federal construction projects, in many cases, as the first application of advanced technologies to demonstrate the usefulness and economic viability of the technologies.

3. By being a catalyst in helping to bring the very fragmented construction industry together for the development, dissemination and user support of beneficial technologies.

4. By participating with and in various organizations - private, governmental and academic - which may be pursuing activities with the same motive. This approach is synergistic and avoids duplicative investments.

I believe the CPAR Program is showing that the industry will respond to leadership and partnership. In addition, it shows that it is possible for more CPAR-like initiatives to be developed by other agencies, perhaps in specialty areas of the construction business such as financing or codes and specification development.

Mr. Chairman, this concludes my remarks. I will be glad to respond to any questions you may have.

Mr. **Walgren**. Thank you, Mr. Pfeiffer. We appreciate it.

I turn to Mr. Morony.

Mr. **Morony**. Mr. Chairman and subcommittee members, the Department of Housing and Urban Development appreciates the opportunity to appear before you to discuss the issues of research and development in the construction industry.

With your permission, I will submit my testimony for the record and summarize it here.

Mr. **Walgren**. We certainly would appreciate that. Feel free to outline your comments in whatever way you would like to proceed.

Mr. **Morony**. Thank you.

You have asked me to focus my testimony on automated factory fabrication for affordable housing. As you know, one of Secretary Kemp's priorities is affordable housing, and we are looking at a wide variety of ways to help make housing more affordable.

In order to respond to your request, I first need to define some terms and clarify the role that the cost of the house itself plays in the affordable housing equation.

First there is manufactured housing, produced under the Federal Manufactured Housing Safety and Construction Standards, which some call the HUD Code, and modular housing meeting one of the State model building codes.

Factory fabrication, however, can have other meanings. Panelized housing, for example, involves the production of complete wall panels, which are then assembled on site into completed houses. Similarly, pre-cut housing involves all structural elements to size in the factory.

Perhaps the most important factory fabrication activities today, however, involve the production of building components such as roof and floor trusses, pre-glazed and assembled windows, and pre-hung doors.

The joint venture for affording housing demonstration projects show that the costs could be reduced by as much as 30 percent. However, the principal factors in these reductions were the amount of land used for housing, the use of innovative utility infrastructure concepts, and the efficiency with which participating local governments processed permit applications. Cost savings due to innovations in construction methods were very limited.

What is the place of innovative materials in affordable housing? Many alternatives to conventional wood framing systems have been proposed over the years. Some have taken hold in the home building industry. No builder uses "one by" boards for wall or roof sheathing any more. Instead, sheathing is usually plywood, flake board, or one of the special insulating panels.

Another new material, developed with HUD assistance by the U.S. Forest Service over the last 15 years, is "Com-Ply". This is a form of dimension lumber fabricated from plywood sheets which provide a nailing surface and a core of processed wood chips which otherwise would be waste material at the saw mill. A few plants are now producing it commercially, and a few builders are using it. But acceptance comes slowly in the housing industry.

This raises one of the key problems facing all U.S. construction, but primarily the housing industry: how can a new product or a new system be evaluated and found acceptable for use in housing in all market areas? There is no nationwide system for evaluating and accepting innovative building materials, systems and methods. HUD has studied the problem, the National Institute of Building Sciences has studied the problem, and the building code groups have studied the problem. To date, there is no resolution.

Given all this, what can the Department do to encourage affordable housing? Several things. First, we can provide the focus to bring the issue to the American public, and to those States and local officials who must take much of the action needed to overcome the barriers of regulation. Secretary Kemp has stressed in numerous appearances before Congress and around the Nation the need to reduce unnecessary regulatory barriers to affordable housing.

Second, we can take steps to help new technologies reach out for evaluation and acceptance.

Third, we can assure that manufactured housing building under the HUD Code is, in fact, safe, sanitary and durable. We are constantly seeking, in conjunction with the manufactured housing industry, to improve the quality of this industry—of this housing, rather.

Fourth, we can and will work with the housing industry to develop and implement appropriate national standards, palatable to the States, to help make factory-built housing acceptable all across the country.

Fifth, we can encourage the private sector to address basic issues which may be holding up industry research and development. An example of this is a current project with the U.S. Forest Products Laboratory of the U.S. Department of Agriculture, looking at the issue of moisture in roofing systems and manufactured housing. Given the limitations of and other demands on HUD's research budget, any such program must be carefully designed to identify and solve specific problems facing the industry.

I recognize, Mr. Chairman, that I have gone beyond my assigned topic, but I believe it is critically important to you and to the subcommittee realize that a concentration only on factory production of housing will have some, but very limited, impact on housing affordability. The issues are complex and cannot be solved by Federal action only.

Thank you.

[The prepared statement of Ronald J. Morony follows:]

TESTIMONY OF

Ronald J. Morony, Director
Innovative Technology and Special Projects Division
U. S. Department of Housing and Urban Development

before the

Subcommittee on Science, Research and Technology

Committee on Science, Space and Technology
U. S. House of Representatives

Hearing on Research and Development in the Construction Industry

September 12, 1985

Testimony of

Ronald J. Morony, Director

Innovative Technology and Special Projects Division

U.S. Department of Housing and Urban Development

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Hearing on Research and Development in the Construction Industry

September 12, 1989

Introduction

Mr. Chairman and Subcommittee Members, the Department of Housing and Urban Development appreciates the opportunity to appear before you to discuss issues of research and development in the construction industry. You have asked me to focus my testimony on automated factory fabrication for affordable housing. As you know, one of Secretary Kemp's priorities is affordable housing, and we are looking at a wide variety of ways to help make housing more affordable.

In order to respond to your request, I first need to define some terms and clarify the role that the cost of the house plays in the affordable housing economic equation.

"Automatic factory fabrication for affordable housing" presents an image of a factory with raw materials delivered at one end, and complete houses coming out the other, ready for occupancy. This image is accurate with respect to two types of housing, manufactured (or mobile) housing produced under the Federal Manufactured Housing Construction and Safety Standards, which some call the "HUD Code," and modular housing meeting one of the model building codes produced by a number of firms around the country.

While both manufactured and modular housing are significant elements in the housing market, they still provide a relatively small fraction of the approximately 1.5 million homes built each year; for example, HUD's Office of Housing estimates that some 215,000 manufactured housing units are likely to be produced each year for the near future.

"Factory fabrication," however, can have other meanings: "Panelized housing," for example, involves the production of complete wall panels, with or without finish on one or both sides, which are then assembled on site into completed houses. On occasion, panelized homes utilize "wet core" modules consisting of kitchens, bathrooms, and utility areas where all or most of the plumbing and primary electrical service is assembled in the factory.

Similarly, "pre-cut housing" involves cutting all structural elements to size in the factory, pre-drilling or providing other connections as necessary, and shipping these elements to the site for assembly. This technique was used extensively by Levitt Homes, among others, in the 1950s and 1960s and several firms still produce custom homes in this form.

Perhaps the most important "factory fabrication" activities today, however, involve the production of building components such as roof and floor trusses, pre-glazed and assembled windows, and pre-hung doors. With new computer-assisted design, layout, and manufacturing techniques, truss manufacturers are able to custom design and fabricate roof and floor trusses for specific applications at costs much less than building these same units on-site.

Factory Fabrication as a Factor in Affordable Housing

The concept that housing costs can be significantly reduced by producing homes in factories, perhaps utilizing new materials and structural systems, has been around literally for decades. This was the idea behind the "Proxmire amendment," Section 108 of the Housing Act of 1968, and former Secretary Romney's idea in Operation Breakthrough that houses could be produced like automobiles.

To the extent that lower-priced labor can be employed in factories, production can be continued irrespective of the weather, and careful planning can reduce material waste, factory-produced housing can reduce the cost of a house delivered to the shipping dock. However, this is not the whole story.

Houses can be built like automobiles, but -- except for manufactured homes -- they are not sold like automobiles. Completed houses cannot be shipped to a dealer, either sold or on consignment, pending their purchase by and delivery to home buyers. For all practical purposes, every house coming out of the factory must be sent to a specific piece of land, either for a known customer or as a speculative investment by a developer. In periods of high housing demand, the market may be able to accept all units produced in the factory; however, experience has shown that in many cases factories are producing at a level well below capacity. This, in turn, means that the factory overhead must be absorbed in the sales of fewer units, increasing the cost of each unit proportionately.

In this situation, it is easy for the additional cost per unit due to lower production rates to exceed any potential savings resulting from the more efficient use of labor and materials in the factory production of housing.

For example, the Joint Venture for Affordable Housing demonstration projects, which were built between 1982 and 1986, showed that costs could be reduced by as much as 30 percent, with 20 percent reductions being achieved in several locations. However, the principal factors in these reductions were in the amount of land used for housing, the use of innovative utility infrastructure concepts, and the efficiency with which participating local governments processed permit applications. Cost savings due to innovations in construction methods were very limited.

The Value of Factory Production of Housing Components

The dependency of factory production of complete houses on market factors, noted above, does not apply generally to the production and marketing of components such as roof and floor trusses, windows, and doors, if the housing market is at all active. For one thing, these components can be used in almost all housing, so their market is not limited to the currently acceptable "style" of housing. For another, they can easily be modified to meet the specific requirements of the builder/developer using them in his or her product.

The important thing to note here is that the market acceptance of a complete house has a significant impact on the economic feasibility of a factory-built home, but not on the value of factory-produced components. As a result, such components are now the norm in residential construction; it is very unusual for builders to frame roofs with rafters or site-built trusses, or to hang doors or glaze windows on site.

The Place of Innovative Materials in Affordable Housing

Many alternatives to conventional wood framing systems have been proposed over the years; these include panels with foam or honeycomb cores, cast-in-place or pre-cast concrete panels or boxes, glass fiber-reinforced plastic molded to look like traditional materials, and various kinds of structural panels using wood, paper, or other fibers. Some have taken hold in the home-building industry; no builder uses "one by" boards for wall or roof sheathing any more. Instead, sheathing is usually plywood, flake board, or one of the special insulating panels. The larger sheets are easier to handle, require less cutting and fewer fasteners, provide greater structural strength, and can be installed much more quickly.

Another new material, developed with HUD assistance by the U.S. Forest Service over the last 15 years, is "Com-Ply." This is a form of dimension lumber fabricated from plywood sheets which provide a nailing surface, and a core of processed wood chips which otherwise would be a waste material at the sawmill. A few plants are now producing it commercially, and a few builders are using it. But acceptance comes slowly in the housing industry.

The Problem of Acceptance

This raises one of the key problems facing all U.S. construction, but primarily the housing industry -- how can a new product or new system be evaluated and found acceptable for use in housing in all market areas? At one time, in the late 1930s and 1940s, most residential builders designed and built their homes to qualify under the Federal Housing Administration's Minimum Property Standards. Few communities had building codes covering single family housing, so housing meeting the MPS was generally considered as being of adequate quality.

In the 1940s through the 1960s, individual communities and States developed building codes; in time, regional associations of building officials developed the model codes as we know them today, and local communities adopted these, often with modifications meeting local concerns. When homebuilding was primarily a local activity, this situation was not a problem. The local materials supplier and builder knew which materials and products were acceptable to the local code and building official, and stocked and used them. But when buildings and components began to be fabricated and assembled in factories, the problem of local acceptance became critical.

A number of attempts have been made to solve this problem. In Operation Breakthrough, HUD encouraged a number of States to enact Statewide "industrialized housing codes" which pre-empted local codes and inspections for factory-built housing within that State. On a broader basis, the three major model code bodies jointly established the Council of American Building Officials (CABO), which in turn has published a "One and Two Family Dwelling Code." This has helped provide a common basis for considering new materials and methods.

But there is no nation-wide system for evaluating and accepting innovative building materials, systems, and methods. HUD has studied the problem; the National Institute of Building Sciences has studied the problem; and the building code groups have studied the problem. To date, there is no resolution.

The Problem of Regulations

The lack of a nation-wide product acceptance system is but one item in the whole issue of regulatory barriers to affordable housing. These have been documented in national studies, in testimony before Congress, and in HUD and other reports over many years. These barriers include building codes which require one particular material or system, or prohibit economical alternatives such as the use of plastic pipe in domestic water systems; zoning regulations requiring excessive amounts of land for each home; site development regulations which do not reflect changes in the technology of inspection and repair of utility systems;

street design requirements which have the effect of mandating Interstate quality construction for side streets; and many similar items. As noted earlier, a major barrier is the existance of administrative procedures which require multiple submissions to many different offices, all adding time and cost to the project.

As I noted earlier, Secretary Kemp has testified to the Housing Committees that affordable housing is one of his priority areas; in particular, the issue of regulatory barriers to innovation continues to be a key concern of the Department. These barriers are primarily State and local in nature, and HUD's impact on them will depend upon the help we can get from each of you as you go back to your constituents with a clear explanation of all of the issues in affordable housing.

HUD's Role in Affordable Housing

Given all of this, what can the Department of Housing and Urban Development do to encourage affordable housing? Several things:

First, we can provide the focus to bring the issue to the American public, and to those State and local officials who must take much of the action needed to overcome the barriers of regulations. Secretary Kemp has stressed in numerous appearances before Congress and around the nation the need to reduce unnecessary regulatory barriers to affordable housing.

Second, we can take steps to help new technologies reach out for evaluation and acceptance. We have the authority to do this within Section 233 and Section 521 of the National Housing Act, under which we can insure the performance of innovations in FHA-insured homes, and accept workable innovations for all FHA-insured projects.

Third, we can assure that manufactured housing built under the Federal Manufactured Housing Construction and Safety Standards is in fact safe, sanitary, and durable. We are constantly seeking, in conjunction with the manufactured housing industry, to improve the quality of this housing.

Fourth, we can, and will, work with the housing industry to develop and implement appropriate national standards, palatable to the States, to help make factory-built housing acceptable all across the country.

Fifth, we can encourage the private sector to address basic issues which may be holding up industry research and development. An example of this is a current project with the Forest Products Laboratory of the U.S. Department of Agriculture looking at the issue of moisture in roofing systems and manufactured housing. Given the limitations of, and other demands on, HUD's research budget, any such program must be carefully designed to identify and solve specific problems facing the industry.

I recognize, Mr. Chairman, that I have gone beyond my assigned topic, but I believe it is critically important that you and the Subcommittee realize that a concentration on only factory production of housing will have some, but very limited, impact on housing affordability. The issues are complex, and cannot be solved only by Federal action.

Thank you.

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Mr. WALGREN. Thank you, Mr. Morony.

Mr. Cheney.

Mr. CHENEY. Thank you.

Mr. Chairman and members of the subcommittee, CRS really appreciates this opportunity to contribute to your hearing.

As requested by the subcommittee, my testimony focuses on Japan's construction R&D. My testimony is primarily based on a year that I recently spent in Japan, during which I was able to visit a number of the large Japanese construction research centers, and also was able to have many informal conversations with Japanese Ministry of Construction officials.

In my testimony I would just like to hit a few key points and then refer people to my written testimony for more detail.

The first point I would like to make is that Japan is doing more construction R&D than the United States. Although in some categories of construction related R&D, such as Government-funded R&D and construction-related R&D and industries outside the construction industry, like construction machinery and materials, the U.S and Japan are doing similar amounts of research.

In one key category, Japan is doing much more. Construction companies in Japan are spending about 15 times as much as American construction companies on R&D. The numbers are about 800 million dollars per year for Japanese construction companies, compared to about 50 million dollars per year for American construction companies.

For all construction related research, the difference isn't as dramatic. Japan might be spending about twice as much as U.S. construction companies. But for actual R&D conducted by construction companies, the Japanese companies are doing much more.

This leads to my second point, which is that most construction related R&D in the United States is conducted outside of the construction industry, in universities, in Government laboratories, and in other industries. But in Japan, a very large percentage of the construction related R&D is conducted by the construction companies. Large Japanese construction companies each have their own research institutes and fund a great deal of R&D. Several Japanese construction companies fund more R&D on their own than all U.S. construction companies combined. Several conduct maybe four times as much as the Center for Building Technology at the National Institutes of Standards and Technology.

I visited several of these institutes and they are very impressive. They have extensive experimental facilities, such as shake tables to simulate earthquakes, acoustic rooms, wind tunnels, and various materials testing facilities.

They are also conducting a very impressing array of R&D. They are doing a lot of research on robotics, they're doing research on computer-aided design, clean rooms for semiconducting manufacturing, and even—I'm reminded of this as I look around this room. They're doing designs for lunar cities, looking ahead to the technology they'll need in the 21st century.

When one visits these centers, one clearly gets the impression that the development and management of technology is really a key part of the construction company's mission in Japan. They use it not only to compete better in existing markets, but even to create and develop new markets.

I don't mean to suggest that U.S. companies, that all U.S. companies aren't good managers of technology. Some are. But I think the Japanese construction companies on the whole are putting more emphasis on it, particularly on the development of new technologies.

The next point I would like to make is that there are many advantages to this way of doing R&D in the construction companies. First, because the same organization that does the research is also using it, they don t have the same kind of technology transfer problem that we have in getting the research from the labs to the users. Also, all the research that comes out of the company labs, or a large portion of it, is proprietary technology.

In addition, the emphasis on technology in all these companies makes them better consumers of technology that's developed elsewhere. And finally, they're able to do a lot of their own testing. Testing of new construction and building technology is often a big barrier to using the technology. The extensive testing the Japanese construction companies do helps break down this barrier and gives clients confidence that a new technology will work. In the U.S., it's harder to find the people that do this.

The next point I would like to make is that most observers—and some of the other people on the panel have already mentioned this—feel that this difference in the amount of construction technologies is giving Japan a lead in many key areas of construction technology. Today, there might not be that much difference between the U.S. and Japan. I think the U.S. is still ahead in some areas and Japan is ahead in others. But in the long run, the prospects might not be so good. As other members of the panel mentioned, if we fall behind in construction technology, it could lead to a reduced U.S. share of both the large, something like $90 billion international construction market, and more foreign presence in the $400 billion U.S. construction market.

The next point that I would like to make is that the reason Japanese construction companies conduct a great deal of R&D is something that can't be easily duplicated here precisely. As other people have mentioned, the U.S. construction industry is very fragmented and companies go through boom and bust cycles and they find it hard to maintain a steady R&D program.

The Japanese construction industry is somewhat more organized. The companies cooperate with each other and with the Ministry of Construction and they are able to avoid boom and bust cycles, and there's less risk that some company that's not doing R&D will be able to come in with a low bid and undercut companies that are spending money on R&D. So it's much easier for them to conduct an R&D program, things that it's harder for us to do here.

Some of the other members of the panel have mentioned—There've been a lot of people, a lot of studies that have looked at construction technology issues and problems of productivity in the U.S. construction industry and competitiveness, and they tend to come out with similar conclusions and similar options, and some of the other people on the panel have mentioned these. These are things like using the Federal role as the owner of buildings to stimulate technologies, and to increase technology transfer efforts.

I guess, with that, I'll conclude my statement. I would be happy to respond to any questions you might have.

[The prepared statement of David W. Cheney follows:]

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STATEMENT OF

DAVID W. CHENEY
SCIENCE POLICY RESEARCH DIVISION
CONGRESSIONAL RESEARCH SERVICE
LIBRARY OF CONGRESS

BEFORE THE

SCIENCE, RESEARCH AND TECHNOLOGY SUBCOMMITTEE

OF THE

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

SEPTEMBER 12, 1989

Mr. Chairman and Members of the Subcommittee, the Congressional Research Service appreciates this opportunity to contribute to your hearing on research and development in the construction industry. I was asked to focus on research and development (R&D) in the Japanese construction industry and how it will make Japan more competitive in construction.

My testimony today is largely based on experiences from a year that I spent in Japan, mostly at the Institute for Policy Science at Saitama University. I visited several construction-related government research institutes, two major research centers of large construction companies, and toured several major construction sites. In addition, I had extensive informal conversations with officials of the Ministry of Construction who were fellow visiting faculty at the University. While at CRS, I have also worked on various construction technology issues, such as earthquake technology and funding of the Center for Building Technology at the National Institute of Standards and Technology (NIST).

My testimony will emphasize three main points:

- Japan is conducting more construction R&D than the United States;
- Japanese construction R&D is conducted so that research results quickly lead to improved construction methods and products; and

- Japan currently has a lead in a few key areas of construction technology, but trails in others. Most observers, however, expect current trends to result in an increasing Japanese lead in a growing number of construction technologies.

Finally, my testimony will discuss some policy implications that follow from these points.

Japan is Conducting more Construction Research and Development than the United States

There is substantial agreement on this point, although data on U.S. and Japanese construction R&D are not completely comparable. It is difficult to precisely quantify construction-related R&D because much of the relevant R&D is conducted in or for industries that serve the construction industry, such as materials and machinery. The National Research Council of the National Academy of Sciences in 1986 made estimates of U.S. construction R&D as divided into the following categories:[1]

R&D by construction companies	$54 million
Benefits to the construction industry from R&D conducted in other industries	$838 million
R&D by the Federal Government	$220 million
Other R&D (estimated at ten percent of that described above)	$111 million
Total	$1,223 million

Japanese construction R&D spending is much greater than U.S. spending in the first of these categories, and is probably about the same in the other categories. In the first category, according to the Japanese Government's R&D Survey, Japanese construction companies in 1987 spent 121 billion yen on R&D,[2] equivalent to over $800 million.[3] This is over fifteen times as much as the estimated R&D spending of U.S. construction companies.

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[1] National Research Council, Committee on Construction Productivity. Construction Productivity: Proposed Actions by the Federal Government to Promote Increased Efficiency in Construction. Washington, National Academy Press, 1986. p. 31-45.

In the second category, the Japanese construction industry probably obtains about the same amount of benefits as the U.S. construction industry from R&D conducted in other industries. In industries whose R&D benefits the construction industry, such as various materials and machinery industries, Japanese R&D spending is close to that of the United States.[4]

In the third category, government-sponsored R&D, Japan and the United States also spend roughly comparable amounts. As in the United States, Japan conducts construction R&D at government research institutes and at universities. For example, the Ministry of Construction, which funds its Public Works Research Institute and Building Research Institute, had an FY87 research budget of 5,506 million yen ($36.7 million). The Ministry of Transportation has a research budget of 14,516 million yen ($97 million), some of which, such as research at its Ports and Harbors Research Institute, is related to construction. The Ministry of International Trade and Industry (MITI) funds research on construction materials and in support of the housing industry. The Ministry of Education, Science and Culture, also funds construction-related research in the engineering faculties of Japanese universities.

Therefore, the amount of research that is most directly related to commercial construction technology -- that funded by construction companies - is many times higher in Japan than in the United States. Because of this, the aggregate level of construction R&D funding is also somewhat higher in Japan than in the United States.

Japanese Construction R&D is Conducted so that Research Results Quickly Lead to Improved Construction Methods and Products.

Because a large portion of construction R&D in Japan is done by the construction industry, it leads more directly to new products and construction methods. Most U.S. construction-related R&D is done outside of the construction industry by equipment manufacturers, university laboratories, or Agencies with different primary missions, and is of varying and often uncertain relevance to the needs of the U.S. construction industry. To the extent that it is relevant, the results of the research are available to foreign construction companies as readily as they are to U.S. companies.

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[2] Statistics Bureau, Management and Coordination Agency, Japan. Report on the Survey of Research and Development, 1987. Tokyo, Management and Coordination Agency, March 1988. p. 92-95.

[3] Throughout this report, an exchange rate of 150 yen to the dollar is used to convert yen figures into dollars.

[4] For example, based on data from NSF and the Japanese Government, Japanese industry spends more on R&D than U.S. industry on stone, clay, and glass products and on fabricated metal products, spends equivalent amounts on transportation equipment, and spends somewhat less on machinery and electrical equipment.

Research at Japanese Research Laboratories

The large Japanese construction companies conduct significant amounts of R&D and have their own research institutes. Of the 22 largest companies, 21 performed R&D, spending 55 billion yen ($368 million) in 1987.[5] R&D spending was equivalent to 0.54 percent of sales for these large companies. For comparison, U.S. construction company R&D is estimated to be less than 0.04 percent of sales.[6] At the top of the Japanese construction industry are the "big six" companies which each have annual sales of over $7 billion.[7] Five of these six companies spent over $45 million on R&D in 1986, with one spending $74 million.[8] Some of these companies spend as much on R&D as all U.S. construction companies combined. The big six have been rapidly increasing their research and development funding since 1980.

These corporate research centers have several functions, including developing new proprietary technologies, solving construction problems that arise in projects, supporting technical training of new employees, and serving as a center for technical information.[9] They also serve a marketing function by showing potential clients the company's technology.

These centers have outstanding experimental facilities, including shake tables for earthquake simulation, wind tunnels for analyzing how a new building would affect the wind flow in surrounding areas, sound chambers, materials testing laboratories, laboratories for simulating weathering, and other facilities. Major topics of research at the facilities include:

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[5] Statistics Bureau, Management and Coordination Agency, Japan. Report on the Survey of Research and Development, 1987. Tokyo, Management and Coordination Agency, March 1988. p. 92-95.

[6] U.S. Office of Technology Assessment. Construction and Materials Research and Development for the Nation's Public Works. Staff Paper. Washington, June 1987. p. 3-6.

[7] The Top 250 International Contractors – Foreign Contracts Bouncing Back. Engineering New Record. July 14, 1989. p. 42-57. The "big six" are Kajima, Shimizu, Taisei, Ohbayashi, Takenaka, and Kumagai Gumi.

[8] Hasegawa, Fumio. Built By Japan: Competitive Strategies of the Japanese Construction Industry. New York, John Wiley and Sons, 1989. p. 161.

[9] Kajima Institute of Construction Technology. Science and Technology in Japan. April/June 1987. p. 55-56.

- **R&D to improve construction productivity.** This includes development of new construction methods, robots for various construction applications, computerization of the construction process, and prefabrication.

- **R&D for areas of high technology.** This includes developing and building "intelligent buildings"[10] for information intensive companies and clean rooms for manufacturing semiconductors and other high technology products. They are also developing bioreactors for waste treatment and improving techniques for nuclear reactor construction. Several construction companies now have offices or programs looking at space-related technologies.

- **R&D in construction materials.** Much R&D is conducted to develop or make use of new construction materials, such as carbon fiber cements and new ceramics.

- **R&D related to Japanese environmental conditions.** Japan is subject to earthquakes and has mountainous terrain and limited usable land. Major foci of research include earthquake resistant technologies, tunnel and bridge technology, and technologies for construction of underground spaces, artificial islands, and other offshore structures.

Although research is conducted on similar topics in the United States, little of such research is done by construction companies.

Government research laboratories in Japan, such as the Public Works Research Institute and the Building Research Institute, also have a user-oriented focus. They focus on R&D related to the government's needs, such as to support the design of government-funded infrastructure projects and the development of building codes.

Benefits of Japanese Construction R&D

There are several advantages to this user-oriented approach with which Japan conducts R&D, with a strong emphasis on product and process development. Because the research is done by the companies that will be using it, there are few barriers to getting research results from the lab to the market. This is in contrast to the United States, where research in university and government laboratories often is not used by industry or is not relevant to industry needs,[11] and where it often takes a long time for innovations in laboratories or other industries to be adopted by construction companies. Japanese construction company R&D also often leads to proprietary technology. U.S. Government-funded research is generally not proprietary, and Japanese companies are often able to use the results as quickly as U.S. companies.

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[10] "Intelligent buildings" refers to buildings with information networks and computerized building management (heating, cooling, security, etc.) systems designed in.

The company-based R&D also creates an awareness of technology in Japanese construction companies, making them more intelligent consumers of new technology. The National Research Council observed that a more innovative environment exists in most foreign firms (European as well as Japanese) because R&D has been integrated into overall operations.[12] This enables them to take advantage of new technologies developed outside of the industry more quickly.

Another advantage comes from the Japanese emphasis on testing. Testing is expensive and building owners are reluctant to buy untested technology, which creates a major barrier to gaining the acceptance of a new technology. In Japan, much of the construction industry's research is devoted to testing products, and the research centers at the major companies have elaborate testing equipment.

An example is the case of base isolation technology, an important advance in earthquake resistant technology in which buildings are built on large shock absorbers that dampen earthquake shaking. It is being used in new buildings at a much faster rate in Japan than in the United States. One reason for the more rapid acceptance of this technology in Japan is the extensive testing and demonstration of the technology by Japanese construction companies. In Japan, the large construction companies are spending $14-19 million per year on base isolation research.[13] For comparison, U.S. base isolation research is primarily funded by the National Science Foundation at about $500,000 per year. Many Japanese construction companies built base isolated demonstration buildings for their own use to test the technology before marketing it more extensively. In the United States, no organization, including the Federal Government,[14] performs this testing and demonstration function.

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[11] The Task Force on Foreign Influences. Foreign Influences in the US Building Industry -- Report to the Board of Directors. Washington, National Institute of Building Sciences. May 1989. p. 37.

[12] National Research Council, Committee on the International Construction Industry. Building for Tomorrow: Global Enterprise and the U.S. Construction Industry. Washington, National Academy Press, 1988.

[13] Eggenberger, A. J. in Preface to: Kelly, James M. Base Isolation in Japan, 1988. Report to the National Science Foundation. Berkeley, CA, Earthquake Engineering Research Center, University of California, Dec. 1988. p. v.

Why Japan performs more construction research than the United States

Some people assume that Government subsidies are the main reason for the relatively high levels of private sector construction R&D in Japan. In general this is not true. Japan does have a tax incentive to promote industrial research and development -- an amount equivalent to 20 percent of the R&D costs that exceed the highest R&D costs in previous years is deductible from corporate income taxes[15] -- but this is little different than the U.S. R&D tax credit (which is currently scheduled to expire at the end of this year). Of greater importance is the general structure of the Japanese construction industry, which the Ministry of Construction has an important role in shaping and maintaining.

Although Japan's construction industry R&D spending is high compared to that of the U.S. construction industry, it is not high compared to other U.S. or Japanese industries. The Japanese construction industry, as described above, spends about 0.5 percent of sales on R&D. Mature industries in the United States, such as automobiles, steel, and textiles spend as much or more on R&D as a percentage of sales than does the Japanese construction industry.[16] So one might ask, why do U.S. construction companies perform so little research?

There are several reasons. The National Institute of Building Sciences (NIBS) has noted that the separation of design and building in the U.S. industry means that no one entity has responsibility for the entire building, and no one can capture the full benefits of research.[17] Contractors have little incentive to do R&D because they are constrained by the specifications in the design. In addition, the wide swings in construction demand also inhibit R&D -- U.S. construction companies put their money away for hard times rather than invest in R&D. NIBS also identified the fragmented nature of the industry combined with strong internal competition as reducing the ability to conduct R&D.[18]

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[14] Dynamic Isolation Systems, Inc. Earthquake Engineering Technology Innovation Roadblocks: A GSA Case History. Briefing papers by Dynamic Isolation Systems prepared for David Cheney of the Congressional Research Service, Dec. 1987.

[15] Agency of Industrial Science and Technology -- 1987. Ministry of International Trade and Industry, Tokyo, 1987. p. 15.

[16] National Research Council, Committee on the International Construction Industry. Building for Tomorrow: Global Enterprise and the U.S. Construction Industry. Washington, National Academy Press, 1988. p. 41.

[17] The Task Force on Foreign Influences. Foreign Influences in the US Building Industry -- A Report to the Board of Directors. National Institute of Building Sciences. Washington, May 1989. p. 26-27.

In Japan, many of these disincentives do not exist. A construction company's income is more predictable[19] because the Ministry of Construction looks out for the interests of construction companies and construction companies cooperate with each other to avoid boom and bust cycles for any company. The large companies tend to rotate as the lead contractor on large projects.[20] Because income is more predictable, it is easier for Japanese companies than American companies to maintain the overhead of an R&D facility. Because all major Japanese construction companies fund R&D, and because foreign competition has been effectively excluded from the Japanese market, contractors do not risk being undercut by companies that are not funding research. In addition, because companies compete less on price, they may compete more on technology and strive to get an advantage by doing construction that other companies are not technically competent to do. R&D also helps lower costs, opens up new markets, and convinces customers of the excellence of their products.

Other factors also encourage Japanese R&D. Japanese companies in general are well known to invest for the long term more than American companies, in part because lower costs of capital allow them to make lower returns on investments, and in part because bank funding results in less pressure from shareholders for short-term returns on investments than equity funding. In addition, lifetime employment makes it more likely that the know-how developed by a company will stay with the company. Finally, the natural environment in Japan also encourages construction R&D. Buildings need to withstand earthquakes and the mountainous terrain means that roads and railroads require tunneling through complex geology. As a small country with few natural resources, Japan must excel in technology to prosper, and Japan has been trying to catch up with the West in technology since the 1870s.

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[18] Ibid.p. 26-27.

[19] Paulson, Boyd C., Jr. Transportation Construction in Japan. Stanford, CA, Department of Civil Engineering, Stanford University. Technical Report No. 240. August 1979. p. 14.

[20] For a critical view of this system, see Van Wolferen, Karel. The Enigma of Japanese Power. New York, Alfred E. Knopf, 1989. p. 118.

Japan May Lead in a Growing Number of Construction Technologies

Most studies suggest that Japan and the United States are roughly equivalent in construction technology today, with the U.S. having a lead in some areas, such as industrial construction, and with Japan having a lead in other areas. For example, a 1984 survey of Japanese construction companies involved in overseas work rated Japan as ahead of other industrialized countries in technology and quality, but behind in other areas that are important for competitiveness in international markets, such as adapting to local culture and business conditions.[21] A 1988 report by MITI, which rated the relative levels of technology and technological development capabilities in various industries, indicated that Japan and the United States are roughly equal in construction and construction machinery but that Japan is ahead in some related areas, such as concrete and steel technology.[22] A U.S. Department of Commerce report states that technology is still an overall comparative advantage for U.S. companies in international competition, but notes that the United States trails European and Japanese firms in developing new construction methods and related specialized equipment, and in tunneling, bridge building, and concrete construction.[23]

There is greater concern about the future. The Department of Commerce report cautions that over the long run U.S. firms are likely to be at a disadvantage because of their underinvestment in the development of new construction technologies, especially in such areas as robotics, automated equipment, light-weight materials, and prefabrication.[24] Others have noted that Japan is ahead in intelligent buildings[25] and some earthquake resistant construction technologies. Japan is likely to develop or extend its technological lead in areas where it is more active than other countries, such as underground construction, earthquake technologies, and offshore development.

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[21] Hasegawa, Fumio. Built By Japan: Competitive Strategies of the Japanese Construction Industry. New York, John Wiley and Sons, 1989. p. 96-97.

[22] Tsusho Sangyosho [MITI]. Sangyo Gijutsu no Doko to Kadai [Trends and Topics in Industrial Technology]. Tokyo, 1988. p. 32.

[23] Capital Goods and International Construction Sector Group, International Trade Commission. A Competitive Assessment of the U.S. International Construction Industry. Washington, U.S. Department of Commerce, February 1989. p. 34 and 73.

[24] Ibid. p. 73.

[25] The Task Force on Foreign Influences. Foreign Influences in the US Building Industry -- A Report to the Board of Directors. National Institute of Building Sciences. Washington, May 1989. p. 23.

How serious is this scenario for the United States? Some people see these trends in technology as leading to a reduced share of the international construction market (currently 27.5 percent of a $94.1 billion market[26]) and a greater foreign share (currently 3.5 percent[27]) of the $350 billion U.S. construction market. Equally important, a failure to innovate means lost opportunities to improve the quality and lower the cost of constructed facilities.

On the other hand, some groups point out that the U.S. construction industry is not likely to go the way of the other industries where the United States has lost markets to Japan, such as steel, automobiles, or electronics.[28] One reason is that buildings are not easy to export, and a large portion of the construction industry is always likely to remain native to any country. Another reason is that the U.S. construction industry is currently quite competitive in world markets, and technology is only one of many factors in competitiveness. Another reason is that architectural styles and construction have to be appropriate for the environment and culture of a country, and many of Japan's strengths in construction, such as in developing underground spaces, are less needed here.

Policy Implications

Studies by the National Academy of Sciences, the Department of Commerce, the Office of Technology Assessment, the National Institute of Building Sciences, and the Business Roundtable in recent years have reviewed productivity and competitiveness in the construction industry. All of these have reached somewhat similar conclusions -- that the United States is at risk of falling behind in construction technology and that steps should be taken to improve technology development in the U.S. construction industry. Among the options listed by one or more of these studies are:

Encourage More Private Sector Construction R&D. Suggested means include extending or enhancing R&D tax credits or establishing private sector research consortia with funding from both the U.S. Government and the private sector.

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[26] The Top 250 International Contractors -- Foreign Contracts Bouncing Back. Engineering New Record. July 14, 1989. p. 42-57.

[27] U.S. Department of Commerce. U.S. Industrial Outlook 1989. Washington, U.S. Department of Commerce, 1989. p. 1-1 to 1-14.

[28] The Task Force on Foreign Influences. Foreign Influences in the US Building Industry -- A Report to the Board of Directors. National Institute of Building Sciences. Washington, May 1989. p. 23.

Use the Federal Role as Purchaser and Financier to Stimulate Construction Technology Development. This could be done by such means as giving a preference to new technologies in awarding Federal contracts, by giving a preference to contractors that fund their own research, or by setting aside a portion of all Federal construction dollars for contractor R&D.

Increase Technology Transfer Efforts. Increased funding could be allocated to getting the results of research from Federal laboratories to the private sector, and to acquiring and disseminating construction technology information from other countries.

Increase Federal Funding for Construction R&D. Funding for construction R&D activities at NIST, NSF, and other Federal agencies could be increased.

Create an Institutional Focus for Construction Competitiveness. An organization could be created, in the Technology Administration of the Commerce Department or elsewhere, to work with industry to identify and support activities that would improve the competitiveness of the construction industry.

Thank you again for the opportunity to contribute to this hearing. I would be pleased to respond to any questions you may have.

Mr. **Walgren**. Thank you, Mr. Cheney. We appreciate that outline for us.

The Chair would like to recognize the gentlelady from Maryland for her—her time at this point.

Mrs. **Morella**. I thank you very much, Mr. Chairman. That's a very nice courtesy you're extending to me because you know I have to go to a Civil Service Committee meeting.

I just wanted to make sure that something I take for granted is that Dr. Wright knows how proud I am of what NIST has been doing. NIST is in the district that I'm honored to represent and the Center for Building Technology has been a great innovator and I appreciate the testimony of all of you.

A very brief question, predicated on the fact that just recently in the State of Maryland, we had the collapse of a bridge, Baltimore/Washington Parkway, and I think it was in the situation of construction at the very time that that happened.

I'm wondering, what is this saying to us, and this would be directed to—to all of the panelists who might like to comment, and does it also pose the problem that State and maybe local codes are a barrier to the model codes that are being established in terms of innovation? What went wrong? What would be the recommendation that would remedy that kind of thing from happening?

Mr. **Wright**. Mrs. Morella, there are a couple of parts in which I will try to answer your question and I will appreciate your asking again points upon which I may not be right on the target of the question.

Taking that specific accident on the Baltimore-Washington Parkway, that is under investigation now, an investigation sponsored by the Federal Highway Administration. We don't yet know the technical reason for that collapse.

Historically, we at NIST have investigated a number of failures of structures under construction. Unfortunately, normally, the causes are failure to follow well-recognized good practices. So that I can't say that's the cause here on the Baltimore-Washington Parkway failure of just a week ago, but that is very commonly what we find when we investigate a failure.

Mrs. **Morella**. You mean like sloppiness—

Mr. **Wright**. Sloppiness, yes, people not doing what they really should be doing.

Mrs. **Morella**. Again, maybe a distinction our CRS person might find between the Japanese mentality and the American mentality about competitiveness.

Mr. **Cheney**. The Japanese construction industry is certainly known for being very careful and doing very high-quality buildings. Often it might cost more and take more time, actually, than our construction, but they're known for high quality and careful work.

Mr. **Wright**. It's visible that it's a real dishonor in Japan to have one of your employees hurt on the construction site.

Mr. **Cheney**. When an accident like that happens, often they would have the police actually investigate and often have criminal penalties.

Mrs. **Morella**. Any of the rest of you like to comment on whether there are problems with State and local codes not following Federal or model codes, model codes, perhaps?

Mr. **Morony**. I'd be happy to, Mrs. Morella.

That is one of the things—

Mrs. **Morella**. It would really be your area, right.

Mr. **Morony**. Yes, ma'am. This is one of the things that the Department has looked at very heavily in all our work on affordable housing over the years. The problem generally gets to be the model codes are quite up to date, but a lot of localities are, one, using an out-of-date code or two, make local modifications—technical modifications which are for a variety of local reasons. And that normally increases the cost of housing.

Very few of them will make it less safe, but they will very frequently make it more expensive.

Mrs. **Morella**. So they're less reticent to accept innovation because of local situations?

Mr. **Morony**. That's correct. A lot of times, they're protecting a local industry. They may not allow one particular product in the code because they produce a competing product locally.

Mrs. **Morella**. I was also interested in what you said about CPAR and—

Mr. **Morony**. Yes.

Mrs. **Morella**. —and what agencies, for instance, you think might well adopt that plan, particularly in the construction industry. I think you said finance—

Mr. **Pfeiffer**. Those were just suggestions. We do know that financing is a problem and the other I mentioned is codes and specifications and certainly we do talk with Dr. Wright and other agencies involved in codes and specifications. Perhaps there are ways that this approach could be used for some imaginative work with industry.

I'd like, if I could, to say a couple more words on the business of codes and specifications that is clearly a slow process in the United States. We are conservative. The fact that there is liability and big suits that come from failure on the job site—there's a great understandability to the fact that a firm would be—want to be very conservative in its approach and not launch out on a new material which might expose them to liability, especially if it were outside an accepted code.

So this is a problem we're going to have to address to find a way to speed up true good testing and get that acceptance throughout the industry much quicker. Because of the fragmentation, it's not going to be easy, but it doesn't mean we shouldn't approach it.

Mrs. **Morella**. Could HUD use the CPAR techniques?

Mr. **Morony**. We try very hard to keep up to date with what's going on and anything that we can get, we use. One of the things we do is—I personally sit on several standards committee that NIST is chairing to try to help develop standards that would be used by the private sector and the public sector as well.

Mrs. **Morella**. I want to thank the panelists and I want to thank my distinguished chairman for allocating me the opportunity to question first.

Thank you.

Mr. **Walgren**. Thank you, Mrs. Morella.

The gentleman from Alabama.

Mr. **Browder**. Thank you, Mr. Chairman.

I have a couple of general questions that I'd like to address to the panel, but first a specific question for Mr. Morony. You talk about HUD's role in affordable housing. You say, given all of this, what can the Department of Housing and Urban Development do to encourage affordable housing and you list several things that we can do.

Would you mind looking back through that list and telling me which one you think you are doing the best job with and which one you are doing the worst job with, because, you know, you've got about five things you say we can do.

Mr. MORONY. Yes, sir. We—actually, I should have said things that we have been doing and are doing. All these things are efforts that the Department has been doing and will continue to do.

For example, talking about the need to overcome barriers, local barriers—regulatory barriers, Mr. Kemp continues to talk about that and there may be—we are working on some initiatives there.

I would be happy to provide some more information for the record on that if you would like, sir.

Mr. BROWDER. Yes, but could you briefly look through those and give me just a quick evaluation. Don't go into any detail, but an evaluation of each of those things that we can do or that we are doing.

Mr. MORONY. We have two programs that are already legislatively allowed. Our experimental housing program, which is in my second point, and the technical suitability of products program.

We are using them right now to bring innovations in. The problems with both of those programs—they apply only to HUD-insured housing. We have talked about various things that could be done there. There may be some legislative proposals in the future on that.

The other things are, we work with the private sector, and at times, that is—to be very frank, it is very frustrating, but it is the—we try to do, like in the mobile home code, it is a slow process, but we make progress very slowly.

Mr. BROWDER. Let me ask a couple of just general questions for you. I have had a question for Mr. Pfeiffer, but I think Mr. Cheney led us directly into it with a comment.

Mr. Cheney, in your report or your testimony, you said to the extent that it is relevant, the results of the research are available to foreign construction companies as readily as they are to U.S. companies. My question that I had for Mr. Pfeiffer, but I'll direct it to anybody, is if we increase our technology development effort, how can we be assured that U.S. firms benefit rather than foreign countries and foreign firms walking off with what we've done?

Mr. PFEIFFER. I'll take first crack at that, sir.

One of the things we're doing under the CPAR program is licensing and patenting to the American firm. Therefore, he gets that protection and that's something we're very much aware of as a need. So I think that's a first step and one of the things that we've included in our program. I think that's a big help.

If that licensing and patent—or patents, as the case may be, is indeed granted and is in place, then our firm has a chance to sell that product worldwide. Naturally, our first use would be here in the United States, but I think there's good benefit in our balance of payments if he is selling it abroad.

Mr. **Browder.** Mr. Cheney, would you mind responding to that?

Mr. **Cheney.** I think that's—the Corps of Engineers program is a very good—good start in that. I think probably some of the other Federal programs—obviously we found a lot of research in universities and things like that that's open. It's research that will provide benefits, you know, many years from now, but often the Japanese construction companies or other construction companies, who are in some ways more progressive in technology are just as good or better at getting some of that information than U.S. companies are. But I think programs like the Corps of Engineer programs are a very—are a very good way of addressing that problem.

Mr. **Wright.** Mr. Browder, if I could add to a response, we at NIST focus our work on things that are not proprietary and so, of course, this problem of being sure that it's useful to the United States is a serious concern for us.

We find the best way to achieve this is that the U.S. users are closely involved with in the research, so that they are aware of the results as soon as they are available, that they're thinking of how to apply them even before the work is done. But it requires a very close partnership between the research-doer and the intended research-user.

It takes initiative not only on the part of the researcher, but on the intended beneficiary to accomplish this.

Mr. **Browder.** I just hope that you're aware and attentive—that everybody's aware of this problem and attentive to it.

My final question, Mr. Chairman, is another general question. One of the criticisms I've heard of American competitiveness is that we do a good job with research, but then, taking that, as you said, from the lab to the market, we don't do a very good job of going back to the lab after having taken it from the lab to the market.

What monitoring do we have to—in translating our research into construction—into the construction market? What follow-up do we have to make sure that, one, it works, or if there are any refinements that need to be made, to make sure that we don't do a lot of research on something and then run out and—run into problems and throw away—wasting that kind of money?

Mr. **Wright.** Let me start with the answer from the viewpoint of NIST. As Mr. Morony mentioned, we are very active on the private sector national standards committees and on a committee which is working with the technology such as plumbing, you have plumbing manufacturers, you have building officials, you have plumbers, people who are active on the committee. So that when we bring the technology to the committee for its application in the practices, we are interacting with users and they regularly come back, saying we're still having this problem or this new problem has cropped up, so our research agenda is constantly influenced by the experience users are having with their technologies at present.

Mr. **Browder.** Mr. Cheney, did you—have you noticed any difference between our follow-up or monitoring here in the United States and what Japan does?

Mr. CHENEY. I haven't observed it carefully enough in Japan to—that aspect of things. One difference that I might notice is that in Japan there is a Ministry of Construction, which has—works very closely with industry, so there is a lot of feedback. If things aren't working, they can very quickly identify problems and solve them.

There's a recommendation that the National Research Council, the National Academy of Sciences made when looking at international competitiveness problems in construction was that there's a lack of sort of a central focus, institutional focus in the U.S. for—for seeing what the needs of the construction industry are in competitiveness and seeing ways to—seeing what's working and what's not working and fixing things if they aren't working.

Mr. BROWDER. So you haven't—you didn't really—haven't paid much attention to that?

Mr. CHENEY. No.

Mr. BROWDER. All right.

Thank you, panel, thank you, Mr. Chairman.

Mr. WALGREN. Thank you, Mr. Browder.

The—I think it was Mr. Pfeiffer, did you—someone mentioned that productivity has gone down since 1969 or so and another had cited the fact that our share of foreign construction is sharply down in these years, down some 60 percent. What's the greatest contributor to the loss of productivity and what—to what do we attribute the substantial decline in foreign construction that we carry out abroad?

Mr. PFEIFFER. I'll take a first crack at that, sir, if I might.

It's very difficult, in my view, to assign one critical element to this. It's, rather, a series of things that, taken together, produce the end result, the fragmentation of the industry. It's very difficult to get things across when you have a new technology throughout that. We've talked about that here.

Certainly, lack of new technology, lack of R&D investment is a part of it.

Mr. WALGREN. But that would not reduce productivity, would it? That would—

Mr. PFEIFFER. Not on its own, but it stagnates so you get a relative effect. That's what happens. And, in a technological world, you can't really stay still. If you stay on one plateau, because it is a global market, you start falling behind. That's the net effect of that.

We also have more of a liability situation than we did in the past, financial problems. It is a whole variety of things and this has been looked at by—certainly not studied in detail by the Corps of Engineers, but we have looked at reports on the problems in the industry and these are the things that have come out of it.

Mr. WALGREN. Can I get other comments on the decline in productivity in this area?

Mr. WRIGHT. One—Mr. Walgren, one point that we must keep in mind when we look at the productivity figures is they're a very imperfect measure of the value created by construction. For instance, in recent years, many environmental regulations have been brought to bear on construction sites to keep you from silting up streams or causing hazards to people around the site, but no credit is given to these investments towards productivity. They come in entirely negatively, although they can have very great values for society.

So that we have to look somewhat suspiciously at these productivity figures.

There's also been—and a number of the witnesses have commented on this—a large-scale diversion of work from the field to the factory, so that, in a sense, more value is already in that prefabricated roof truss when it's brought to the site and that is not credited as productivity in terms of the construction activities carried out at the site.

I would not suggest that there is no problem or no need to improve construction productivity, but we have to be skeptical of the figures that are collected.

Mr. **WALGREN**. Other comments on why the—the decline in participation abroad or comments on productivity generally?

Mr. Morony.

Mr. **MORONY**. I agree very much with Dr. Wright. We've been talking about the maybe productivity problem. It is a very complex one and one that there is not a consensus of opinion on. It is something that needs to be looked into, but it's very, very difficult to measure. I agree very much with Dr. Wright on that.

Mr. **PFEIFFER**. With regard to the decline of the U.S. share of the foreign market, there, again, I think it's a multi-faceted problem, one of which is that there are more competitors out there now than there were 20 years ago. Some of the nations that emerged from 20, 30 years ago, that emerged from World War II were not effective competitors because they were getting over the war. Now they are very effective competitors and there are just simply more guys out there playing in the game. That certainly has to be taken into account.

One thing that I might mention also is—and that's why the Corps is undergoing this technical assistance demonstration program and that is the fact that on certain types of work, very specialized facilities are needed to do a job. For instance, if you're doing a job on a breakwater or a port in a foreign country, often specialized model facilities are needed. Those are not usually available on large scale in private firms or in our universities, though in some cases they are.

A foreign firm, for instance, a Dutch firm, might be wanting to bid a foreign breakwater job, a big one, and would have access to routinely the laboratory, a national laboratory. Our firms, by a similar token, up until this recent demonstration, couldn't have access to the Corps of Engineers' major laboratory facilities. We've had a change in law that allows that, so this is a step, we feel, in the right direction along that line.

The foreign firms, to put it in a nutshell, can have access, greater ease of access to their national laboratories than can our U.S. firms for actual work on a job.

Mr. **WALGREN**. And why is that again? I'm sorry, I—I missed it.

Mr. **PFEIFFER**. We have not—we are not able to support until we've had this recent legislation, a U.S. firm wanting to bid on construction. Now, we're not talking R&D anymore; we're talking actual studies of the port, if we're using a port as an example, put model waves against the model of the port and this is the typical way that it's done, but it requires some very specialized, very large facilities that are not usually available in private industry. It usually is done at a national scale, a national laboratory.

Mr. **Walgren**. And you were unable to support that kind of research—

Mr. **Pfeiffer**. That's correct, until recent legislation.

Mr. **Walgren**. That—you mentioned in your testimony the ability to give technical assistance to U.S. firms bidding abroad.

Mr. **Pfeiffer**. Right, that's what my—just—my remarks were given here we're just addressing.

Mr. **Walgren**. I see. In your testimony, you indicated that you might be looking for legislation to allow that—

Mr. **Pfeiffer**. On a continuing basis.

Mr. **Walgren**. —you are doing that on a base of legislation now and it took legislation—

Mr. **Pfeiffer**. Yes. We have a demonstration legislation—demonstration authority for two years and if it works out well, then we would come back and ask for a permanent authority.

Mr. **Walgren**. I see.

What was the prohibition against that prior to the legislation?

Mr. **Pfeiffer**. Federal laboratories simply could not provide that kind of—by the authorities we operate under, could not give that. We can't go into competition with any private firm and, beyond that, we simply had no method when we looked at our authorities to provide that assistance.

Mr. **Walgren**. Is that similar to your experience, Dr. Wright, in the Bureau of Standards?

Mr. **Wright**. We have to be careful not to be in competition with private laboratories for doing essentially routine work. We have, for several years now, been able to work cooperatively with industry when our facilities were unique and needed by the industry in order to do a particular job.

So that we've had research associates from industry working on problems of common interest with us, oh, for 60 or 70 years, and we've had a number of active projects in cooperation with private-sector firms related to the construction industry in recent years.

We can collaborate as long as we're not competing with that standard testing laboratory down the street.

Mr. **Walgren**. We wonder whether there are any sort of general authorities under the technology transfer system that we have in place to allow that kind of access to Federal facilities.

Mr. **Wright**. At NIST, we believe we have the necessary authority for this cooperation.

Mr. **Walgren**. Well, I hope we would look at the other agencies to see as well whether—what those limitations are and perhaps I could ask CRS to maybe raise those questions with major players in other agencies and let's see what comes back.

Mr. **Cheney**. We'd be happy to do that.

Mr. **Walgren**. Let me also ask the general question of how much money we're spending in these areas. Mr. Cheney, in your testimony, you put—you cite the National Research Council's estimates of U.S. construction R&D and that by the Federal Government of $220 million. I guess I'd like to ask how that $220 million is broken down and perhaps you could give us a submission for the record on that or can you at least—

Mr. **Cheney**. I don't have all the numbers—it's the programs from NIST and NSF and the Corps of Engineers, as well as a few others, pulled together. I could get it for the record.

[The information follows:]

The National Research Council estimate of $220 million in U.S. Government construction-related research and development spending includes $119.3 million by Federal agencies responsbile for procuring construction, and $100.8 million in civil engineering R&D by Federal agencies that are not primarily responsible for procuring construction. The construction-related R&D spending at Federal agencies responsible for procuring construction is as follows.

(millions of dollars)

Department/Agency	R&D Expenditures
Department of Agriculture,	
Forest Service	1.9[a]
Department of Defense:	
Army Corps of Engineers	42.7[b]
Naval Facilities Engineering Command	4.0[b]
Air Force Civil Engineering	33.0[b]
Department of Energy	32.2[a]
Department of the Interior,	
Bureau of Reclamation	3.3[a]
General Services Administration	.2[a]
National Aeronautics and Space Administration	1.0[a]
Veterans Administration	1.0[b]
Total	119.3

[a] Source: National Science Foundation (1984a). Includes applied civil engineering research for 1983 and basic civil engineering research for 1984.

[b] Source: Briefings given to the committee (see Appendix B). Includes research, development, testing, and evaluation for FY 1985.

From: National Research Council, Committee on Construction Productivity. Construction Productivity: Proposed Actions by the Federal Government to Promote Increased Efficiency in Construction. Washington, National Academy Press. 1986. p. 38.

Civil engineering R&D spending by Federal agencies that are not primarily responsible for procuring construction is as follows.

(millions of dollars)[a]

Department/Agency	R&D Expenditures
Department of Agriculture, Agricultural Research Service	2.2
Department of Commerce:	
National Bureau of Standards	6.7
National Oceanic and Atmospheric Administration	2.1
Department of Housing and Urban Development	0.1
Department of Interior:	
Geological Survey	4.6
Minerals Management Service	0.9
Office of Surface Mining Reclamation and Enforcement	0.2
Department of Transportation:	
Federal Aviation Administration	8.1
Federal Highway Administration	2.5[b]
Federal Railroad Administration	1.0
Research and Special Programs Administration	.3
Urban Mass Transportation Administration	17.8
Agency for International Development	3.0
Environmental Protection Agency	22.0
Federal Emergency Management Agency	0.2
National Science Foundation	29.1
Total	100.8

[a] Includes applied research for 1983 and basic research for 1984.

[b] The Federal Highway Administration actually transferred more than $30 million to the states for highway planning and research. NSF reports only funds used for basic and applied research.

SOURCE: NSF (1984a).

From: National Research Council, Committee on Construction Productivity. Construction Productivity: Proposed Actions by the Federal Government to Promote Increased Efficiency in Construction. Washington, National Academy Press. 1986. p. 40.

Mr. **Walgren**. How much money is in the CPAR program, Mr. Pfeiffer?

Mr. **Pfeiffer**. Our authority, sir, in the first year, $3 million. The second year, four million; third year, five million; next year, six million; and then a level authority of 6 million per year. It is a cost-sharing program. The government's share cannot exceed 50 percent. So you can—if you just take the rule of thumb, 50/50, that would double all those government figures.

Mr. **Walgren**. And what kind of a share of that is of your actual construction budget?

Mr. **Pfeiffer**. Our actual construction R&D budget in the Corps of Engineers—and I'll speak, just if I might here, we can supply some definitive figures for the record, but just on the civil works program, and we do have both the civil and the military, but I'll speak only for the civil, is between 30- and $40 million a year.

Mr. **Walgren**. So if you allocated 3 million, you would be something like 10 percent?

Mr. **Pfeiffer**. Yes, sir, approximately 10 percent.

Mr. **Walgren**. A substantial percentage.

Did that program come from the Congress? Was that—

Mr. **Pfeiffer**. Yes, sir, special authority.

Mr. **Walgren**. Let me recognize the gentleman from Alabama, Mr. Browder.

Mr. **Browder**. Thank you, Mr. Chairman.

I have another question for Dr. Wright. Dr. Wright, I'd like for you to comment on this and I may have a follow-up question for you.

What kind of—would you comment on the problem, the extent of the problem or the nature of the problem that we have in hardware and software with transferring data from—you're talking about the openness and you cite that as, I guess, a major conceptual approach to our progress here. What kind of problem do we have with hardware and software as far as transferring data from one system to another?

Mr. **Wright**. It's an extremely important problem because, as we look at the disaggregated construction industry, and this variety of small firms that coalesce in different combinations on specific projects, each participant—say he's a specialty contractor that pours concrete—is going to have his own computer hardware and software to manage and control his activities.

And yet, on each project, he's going to be working with other firms who have their own different computer hardware and software so they have this problem of how do they interchange information automatically? If they can't do it automatically, there's a lot of cost in printing out data and then putting it back into another guy's computer and there's big chances for mistakes that can be extremely expensive.

So it is a major problem of this automatic exchange of information between dissimilar computer hardware and software.

Mr. **Browder**. What kind of progress is being made on this problem and what is NIST doing to help with the problem?

Mr. **Wright**. NIST is working very actively with National Standards Committee called IGES/PDES, and that's spelled out—the IGES is the Initial Graphics Exchange Specification and the PDES stands for Product Description Exchange Specification, and the purpose of these National Standards activities are to develop what are called neutral languages that describe products. These are public languages so that everybody knows the dictionary, in a sense.

In this way, you don't have to give away any secrets for your proprietary computer hardware and software. You can organize the information any way you want to inside your machine and you write the translator that translates from your proprietary data system to the public neutral interface language.

Mr. **Browder**. Is any progress being made—

Mr. **Wright**. Great progress is being made on it. There have been issuances of national standards for two-dimensional drawings, for the geometrical things that appear on two-dimensional drawings.

We had a meeting last week at NIST of a committee that's working on the neutral language for three-dimensional piping, something that will be extremely important for the construction industry because one of the biggest costs for putting industrial plants into operation is the three-dimensional piping, making it fit together, avoiding interferences and a lot of information has to be exchanged between different people in this activity.

So it's a very active, ongoing effort. People at NIST and elsewhere have done some very important work on information modeling that will be used in these national and eventual international standards. The progress is good. We're very happy that the Department of Defense support has been available, the Navy is helping because of this importance in reducing the cost of shipbuilding and so it's going well. I wouldn't say that all the resources for optimum speed are available, but it is progressing well.

Mr. **Browder**. Thank you.

Thank you, Mr. Chairman.

Mr. **Walgren**. Mr. Pfeiffer, the—the 3 million and the $30 million figure you cited, the $30 million is what, again?

Mr. **Pfeiffer**. That is our total civil works research budget—

Mr. **Walgren**. I see.

Mr. **Pfeiffer**. —for all of it.

Mr. **Walgren**. What is your total civil works budget?

Mr. **Pfeiffer**. A little over 3 billion, sir.

Mr. **Walgren**. And so 3 million is—is what percent of—

Mr. **Pfeiffer**. About 1 percent.

Mr. **Walgren**. About 1 percent.

The—I guess the question I have is are there other comparable programs in the government? In the National Center for Building Technology, we have about—what's our budget there, the total budget?

Mr. **Wright**. The total budget for the Center for Building Technology is a little over $10 million a year. Of this, about 4 million is directly appropriated, authorized by your committee, and about 6 million comes from reimbursable work done for other Federal agencies and for private sector organizations.

Mr. **Walgren**. All right, and so there's a substantial private sector presence in that that would give some direction to the funds. I'm wondering, at HUD, do we have anything in HUD that's at all similar to a research program where you're receiving suggestions for projects from the private sector that we then can help fund on a cost-shared basis?

Mr. Morony. At the present time, we have the authority to take unsolicited proposals that have cost-sharing by the proposer. The way our budget's been going recently, we don't have any specific funding for that and so they have to eliminate programs that are already approved and—in our budget.

Mr. Walgren. Uh-huh.

Mr. Morony. Most of our research comes from three sources: one, requests from our—from the program offices within HUD; other things we hear about from the—the homebuilders, which we have very close associations with; and congressionally mandated work.

Mr. Walgren. Can you—is there some description you can give us of the actual effort made by HUD in terms of dollars that could be attributed to research?

Mr. Morony. We'd be happy to submit that for the record, sir. I don't have the numbers with me.

[The information follows:]

Q: Is there some description you can give us of the actual effort made by HUD in terms of dollars that could be attributed to research.

A: HUD will obligate approximately $1.4 million on residential and building technology in the course of fiscal year 1989.

Mr. Walgren. Okay. I wonder if we could ask the CRS group to—to look at other major agencies that carry out construction, like the Department of Energy, I gather, must engage in quite a bit of construction. We talked about Army Corps of Engineers on the civil side; how about the military—the—the—

Mr. Pfeiffer. Yes, sir, we do construction related to research on the military side, also.

Mr. Walgren. Do you have any idea what those budgets are?

Mr. Pfeiffer. I'm going to pull a number off the top of my head and, please excuse me if I'm wrong. We will submit the correct figures to the record, but I think our military-funded work that is directed at construction R&D, as we're discussing here today, is in the range of 10- to 15 million per year.

But we will get you some exact figures on that, sir.

[The information follows:]

Military research and development in support of Army military construction was $46.5 million in fiscal year 1988 and $48.7 million in fiscal year 1989. The Army's total military construction program, for these periods, was $1.284 billion for fiscal year 1988 and $1.183 billion for fiscal year 1989.

Mr. Walgren. And on a base of what total construction would that come from?

Mr. Pfeiffer. That number, I don't have it all, sir.

Mr. Walgren. I guess what I'm fishing for is that if this industry is made up of so many little pieces, many of which can't be expected to do any significant substantial research and development, at least we ought to be able to look at the pieces that are substantial and see a—a—a real effort in terms of percentages directed in that activity, I would think, and realizing that it's hard to have good ideas, certainly we ought to be open to ideas from the private sector and so I really would be wondering whether some of these other agencies that are engaged in major efforts do have a way for the private sector to propose a project that might lead us, both to greater efficiency in the construction efforts of that agency, but, of course, also for the economy as a whole.

Mr. WRIGHT. Mr. Walgren, could I comment briefly on the guidance that NIST receives from the private sector for its research?

Mr. WALGREN. Certainly.

Mr. WRIGHT. We work annually with the National Institute of Building Sciences, a private sector organization, which has a membership made up of manufacturers and practitioners in the construction industry, and they regularly give us annually recommendations for our research agenda. We work with an Assessment Panel under the auspices of the National Academies, made up of people from the private sector and universities and they regularly give us guidance on topics that need to be addressed and researched.

For instance, a vice president of Bechtel is on our Assessment Panel, and we work very closely with over 100 national standards committees which are staffed principally by representatives of private sector organizations, industry, professions, contractors and, again, regularly learn from these members of these standards committees where there are technical problems that need to be addressed in order to improve their practices. So we do feel very close to the private sector.

Mr. WALGREN. Does the private sector place researchers in the Center for Building Technology?

Mr. WRIGHT. We have a substantial number of research associates from private industry working with us at the National Institute of Standards and Technology.

Mr. WALGREN. I'd like to ask if you would pull together some outline of the—the topics that you approve for research, I guess, and then perhaps an outline of the ones that are suggested to the Center for Building Technology, but may not have the priority. I don't mean to ask anybody to create a paper, but there must be perhaps an index to a meeting or a—a—the time that people sat down and considered the subjects to pursue that would give us an indication of what was pursued and what was not.

Mr. WRIGHT. Yes, sir. We will be very happy to submit for the record a summary of the relatively formal requests that we have had from the National Institute of Building Sciences and from our Assessment Panel for undertaking research in various areas and indicate those that we've been able to plan for and those that we've not been able to plan for.

[The information follows:]

UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
(formerly National Bureau of Standards)
Gaithersburg, Maryland 20899

October 18, 1989

Honorable Doug Walgren
Chairman, Subcommittee on Science,
  Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

This transmits the information about the Center for Building Technology's (CBT) of the National Institute of Standards and Technology interactions with the private sector you requested during your September 12, 1989 hearings on Research and Development in the Construction Industry.

CBT's research activities are based largely on recommendations from the private sector. We have strong ties to the construction industry, academia, and others of the private sector. Our researchers work closely with their peers to assure cognizance of research developments and that research efforts are complementary. For example over 50 research associates from US industry and visiting faculty members from universities worked at CBT during 1988.

Since 1986, the National Institute of Building Sciences (NIBS) has provided NIST's CBT and the Center for Fire Research (CFR) with recommendations for building research. Members of the NIBS' Committee on Recommendations for Building Technology Research are selected from among NIBS' membership -- a cross-sectional sample of the building industry. Tab A contains NIBS' recommendations for 1990.. The NIBS Committee was created in response to the House Committee on Science and Technology's request that NIST ask NIBS to provide them with annual lists of research recommendations (Bill H.R. 2513, Authorizing Appropriations to the National Bureau of Standards for Fiscal Year 1984, page 15). A Memorandum of Understanding was developed between NIST and NIBS; it covers the development of these annual research recommendations.

Annually, the National Research Council (NRC) of the National Academies through their Board on Assessment of NIST Programs provides guidance and general oversight to the work of about 19 NIST centers and other functional areas. Each NRC Panel considers the importance and relative priority of research projects, quality of staff, equipment needs, finances, and relation of the programs to the mission of NIST. Panel members are selected from leaders of research and practice in industry, academia, and government. TAB B contains the 1988 Assessment Panel for Building Technology's report.

Other examples of CBT's interactions with the private sector include:

1. Participating in over 100 US and foreign standards development committees (our staff chair many of these committees) to transfer research results to practice and learn of research needs.
2. Research is sponsored or supported by the private sector, (see TAB C for a listing of research performed during at least the past three years).
3. Inspection and proficiency sample services are provided to 800 construction materials testing laboratories nationwide which use ASTM and/or AASHTO test methods. This work is performed through CBT's Construction Materials Reference Laboratories (CMRL) which are staffed with 33 Research Associates from ASTM and the American Association of State Highway and Transportation Officials (see TAB D brochure on CMRL).
4. Participating in conferences, workshops, and meetings hosted by the private sector and private sector involvement in NIST conferences including CBT's 20 year old Building Technology Symposia Series (for the latter, see TAB E).
5. Publishing in public domain literature and journals of professional societies and building trade organizations and distributing research findings to targeted professional peers.
6. Responding to about 1000 annual requests from the private sector for information about CBT's program and publications.
7. Hosting visits of officials e.g., manufacturers, regulatory officials, designers and contractors to our laboratory facilities.

We trust this material provides you the information you are seeking. I am available to provide additional material as requested.

Sincerely yours,

Richard N. Wright
Director, Center for Building Technology

Attachments

NATIONAL INSTITUTE OF BUILDING SCIENCES

RESEARCH RECOMMENDATIONS FOR THE

NATIONAL INSTITUTE of STANDARDS and TECHNOLOGY

CENTERS FOR BUILDING TECHNOLOGY AND FIRE RESEARCH

May 18, 1989

National Institute of
BUILDING SCIENCES

The National Institute of Building Sciences is a non-governmental, non-profit organization, authorized by Congress to encourage a more rational building regulatory environment and to accelerate the introduction of existing and new technology into the building process.

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NATIONAL INSTITUTE OF BUILDING SCIENCES RESEARCH RECOMMENDATIONS
FOR THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
CENTERS FOR BUILDING TECHNOLOGY AND FIRE RESEARCH

May 10, 1989

This report contains a series of research recommendations for the National Institute of Standards and Technology's Centers for Building Technology and Fire Research, which have been submitted by numerous representatives of the building community. The report also contains comments and recommendations of NIBS committees formed to review the proposed projects in the areas of Fire Research, Building Environment, Building Materials, and Building Structures.

NATIONAL INSTITUTE OF BUILDING SCIENCES
1201 L Street, N.W.
Washington, D.C. 20005
202-289-7800

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PREFACE

The National Institute of Building Sciences (NIBS) is once again pleased to forward to the National Institute of Standards and Technology (NIST) Centers for Building Technology and Fire Research a series of building community research recommendations. The recommendations, developed over the past year have been reviewed, refined, and accepted by a NIBS project committee. The recommendations include information from the most capable and knowledgeable sources available in the nation's building community.

This fourth annual report, prepared as part of the continuing cooperative effort between the NIST Centers for Building Technology & Fire Research and NIBS, facilitates the exchange of information and ideas between the research sector and other building community sectors. This cooperation has a positive effect on the direction building research follows as well as the support NIST receives from the building community. With the needs of the industry growing and continually changing in an increasingly competitive marketplace, new and expanded research will help keep the nation's building industry competitive both nationally and internationally. This report is a step toward that objective.

Our appreciation is extended to the NIBS project committee chairman, Mr. David B. Mattis, and subcommittee chairmen, Dr. Tage Carlson, G. Day Ding, R. Douglas Stone and Richard A. Vognild, whose knowledge, leadership and highly professional efforts made the completion of this report a success. We also would like to thank the many members of the building community who submitted detailed research topics for consideration by the project committee.

This effort, with continued refinement, will help both NIST and NIBS to improve and expand their endeavors to support the building and housing community and the building construction process. We appreciate the opportunity to serve these two important centers and look forward to a continuation of this excellent cooperative program.

MacDonald Becket, FAIA
Chairman of the Board

David A. Harris, AIA
President

TABLE OF CONTENTS

Chapter	Page
I. Abstract	1
II. Introduction	5
III. Findings and Recommendations	
A. Building Environment	9
B. Building Materials	13
C. Building Structures	16
D. Fire Safety	19
IV. Project Listings	
A. Building Environment	22
B. Building Materials	41
C. Building Structures	50
D. Fire Safety	60
V. Appendixes	69

NIBS RECOMMENDATIONS FOR NIST RESEARCH

CHAPTER I ABSTRACT

This section of the report provides, for those with limited time, a succinct overview of the report contents pertaining to the four major areas of Building Environment, Building Materials, Building Structures and Fire Safety.

The report has been produced once each year for the last three years as a result of an agreement between the National Institute of Standards and Technology (NIST), which conducts basic research, and NIBS, as representative of the building community. Its purpose is to provide to the NIST Centers for Building Technology and Fire Research, an agenda of recommended research projects, detailing the specific needs which the building community feels are appropriate to keep the community progressive and competitive. This cooperative effort provides to the NIST centers another valuable input to use while developing their future building technology research agenda and also provides to NIBS and its members information about building program research being conducted at NIST in which they might have an interest.

Candidate projects for review by four NIBS subcommittees were obtained from the memberships of ten different organizations (see appendix) within the building community and compiled into four lists paralleling both the organizational structures of CBT and CFR and the four NIBS project subcommittees. (Building Environment, Building Materials, Building Structures and Fire Safety.)

The subcommittees were composed of volunteers with extensive expertise in their subject areas. They met in February and March of 1989 to review and prioritize each suggested project, categorizing each as either high, medium, low, or NA (not applicable) for recommended insertion into the NIST research program. Those prioritized as high or medium were then given special subcommittee attention which led to the expanded comments in Chapter III, Findings and Recommendations of this report.

A high assigned priority indicates that the committee feels this project should be undertaken as soon as possible while a medium priority project should be done as soon as resources become available. All the submitted projects, with assigned priorities and brief comments, are included in Chapter IV, Project Listings.

The completed report was voted on by the full committee for approval, and forwarded to the NIBS Board of Directors for final approval. Once this approval was obtained, the report was provided to the NIST for its use.

A listing of the high and medium priority programs or projects in the major subject areas is provided in the following paragraphs. Details on why each project was so categorized can be found in chapter III.

NIBS RECOMMENDATIONS FOR NIST RESEARCH

BUILDING ENVIRONMENT

High Priority

- Revise domestic cold water and hot water pipe sizing procedures.
- Determine test methods to measure the conductive/radiative/convective heat transfer properties of fenestration products.
- Continue work of conducting laboratory measurement of heat transfer across building walls under simultaneous temperature and air pressure differences.
- Obtain further experimental data on the thermophysical properties of CFC replacement refrigerants.
- Determine the effect of building moisture capacitance on air conditioning use.
- Obtain the thermodynamic and transport properties of fluorocarbon refrigerants.
- Evaluate additives or admixtures which assist in the control of moisture in buildings and building components.
- Develop data concerning air distribution to improve room air circulation at desk level.
- Evaluate reductions in R-value due to moisture in wall and ceiling insulation.
- Develop a protocol for communication between control systems.
- Continue work on indoor ventilation and air quality effectiveness.
- Investigate the thermophysical properties of concrete and concrete masonry materials.

Medium Priority

- Determine the effect on energy utilization of the built environment using radiancy for occupant comfort during transient conditions.
- Develop window labeling system for energy efficiency and cost life cycle.
- Evaluate and provide test methods for radiant barrier system thermal performance.
- Determine the effects of aging on radiant barrier materials systems.

NIBS RECOMMENDATIONS FOR NIST RESEARCH

BUILDING MATERIALS

CBT Building Materials Division (BMD) work has been focused in three critical areas - concrete, coatings, and roofing - which have yielded beneficial results to the building community, however due to the current interest in such emerging areas as composites and plastics the subcommittee feels that there may be broader opportunities for the BMD to expand research activities into new areas to support the community.

They also would add that emphasis should be increased by the Building Materials Division on efforts to make members of the building community more aware of their research topics. A continuing challenge for BMD would be to increase marketing efforts to involve the the public and private sectors of the community and thereby significantly increase the availability of funding for needed research.

High Priority

- Determine the effect of high temperatures on glue used in residential structures.
- Develop a methodology for predicting the service life of glued laminated beams and for condition assessment of glued laminated beams in the field when they show signs of delamination.
- Determine in-service single ply membrane durability.
- Determine the performance of building materials and composites under cyclic wetting and drying conditions.

Medium Priority

- Develop NDE application methodologies for wood structures.

BUILDING STRUCTURES

High Priority

- Develop improved non-destructive techniques for constructed facilities.
- Increase the knowledge available concerning connectors between concrete and other materials.
- Conduct research to extend the data for the use of composite columns with high strength concrete.
- Improve data supporting the criteria, test methods and evaluation of

damping characteristics of base isolation systems for structures in seismic areas.

- Conduct research leading to improved design and construction practices to resist windstorms.

Medium Priority

- Evaluate the performance and stiffness contribution of cladding.

FIRE SAFETY

All the Fire Research recommendations were analyzed with regard to the facilities available at the Center for Fire Research and their appropriateness for conduct by the CFR.

High Priority

- Determine the mechanical smoke exhaust effects on fire growth, fire spread and fixed fire suppression systems.
- Which is better for Smoke purge - positive or negative pressure?
- Determine the effectiveness of engineered smoke control systems in large buildings.
- Develop a fire model for charring wall linings in compartments.

Medium Priority

- Investigate how to install fire sprinklers in non-sprinklered existing buildings by use of stand pipe risers or domestic water systems.
- Study the effectiveness of compartmentation in reducing fire hazards.
- Research the toxic smoke hazard of materials in HVAC plenums.

Detailed project listings in the areas of building environment, building materials, building structures and fire research are found in chapter IV. Each project submitted from the building community is presented along with a committee comment and recommendation.

NIBS RECOMMENDATIONS FOR NIST RESEARCH

CHAPTER II INTRODUCTION

The National Institute of Building Sciences (NIBS) has completed this fourth annual report of recommended research projects for the National Institute of Standards and Technology (NIST) in a continuing effort to provide better communication and discourse between the building community and the NIST Centers for Building Technology (CBT) and Fire Research (CFR). Its purpose is to provide to the NIST Centers for Building Technology and Fire Research, an agenda of recommended research projects, detailing the specific needs which the building community feels are appropriate to keep them competitive. The final list of research recommendations are forwarded to the NIST centers in the form of this report.

The report has been produced once each year for the last three years as a result of an agreement between NIST, which conducts basic research, and NIBS, as representative of the building community. This cooperative effort provides the NIST centers one of several sources of input they use to develop their building technology and fire research agenda. This agenda is utilized as a basis for obtaining funding from sources such as the Congress. The effort at the same time, provides to NIBS and its members, information about building programs and fire research being conducted at NIST in which they might have an interest.

For example, the staff of the two NIST centers normally present, on an annual basis to the four subcommittee meetings, information on NIST capabilities, current NIST programs and how the previous years' recommendations were placed into the NIST research program. The process provides an opportunity for interaction between committee members and the NIST staff, including the exchange of project information and technical knowledge.

The Project Committee

To develop the report, a project committee with four subcommittees was formed to review, comment on, and set priorities for a series of specific research projects solicited from the building community. The specific topics for the subcommittees were: Building Environment, Building Materials, Building Structures and Fire Safety. These subcommittees were composed of NIBS members representing the twelve NIBS defined building community sectors. They were formed from respondents to calls for volunteers from the NIBS membership issued in early 1988. The chairmen of each of the four subcommittees, acted as a steering committee to assist the chairman during the technical writing and review portion of the process.

The subcommittees evaluated recommended projects in the four subject areas under the leadership of five volunteer chairmen. Mr. David Hattis served as overall chairman for the project and he was assisted by the following subcommittee chairmen;

Building Environment - R. Douglas Stone, P.E. Chairman

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Building Materials - Dr. Tage C. G. Carlson, Chairman
Building Structures - G. Day Ding, Chairman
Fire Safety - Richard A. Vognild, P.E. Chairman

Project Solicitation

Detailed recommendations and other technical information was collected from the building community through a survey of members of the NIBS councils and other organizations, as listed below, whose members would have expertise or an interest in the project. The names provided by these organizations for the survey were generally chairmen of committees in that organization who would have in interest in a specific subject area such as fire safety or building materials. One organization, the American Consulting Engineers Council, offered additional assistance by providing a random list of interested members.

NIBS Consultative Council, Building Seismic Safety Council,
    Building Thermal Envelope Coordinating Council and
    Wood Protection Council
American Consulting Engineers Council
American Institute of Architects
American Society of Civil Engineers
American Society of Heating, Refrigerating and Air-Conditioning Engineers
American Society of Testing and Materials
Building Officials and Code Administrators International
Building Owners and Managers Association

These persons were then sent one of four packages, either for building environment, building materials, building structures or fire safety, asking for suggested research topics or projects. When the request forms were returned they were categorized by project into one of the four technical areas and put together in a list for review by the project subcommittees. The lists were similar to those included in chapter IV of this report.

The nominated projects, all of which are listed in chapter IV, represent the building community's recommendations for research which could be conducted by the NIST to support the building industry. Seventy-nine individual recommendations were received from fifty-five different survey respondents.

Review Procedure

The subcommittees, composed of volunteers with extensive expertise in their subject areas, met on February 27 (fire research) and March 2, 1989 (building materials, building environment and building structures) at the NIST campus at Gaithersburg, Maryland. They reviewed the project lists for their specific topic and categorized each submitted project as either high, medium, low, or NA (not applicable) for recommended insertion into the NIST research program. Those prioritized as high or medium were then given special subcommittee attention and the expanded comments found in Chapter III, Findings and Recommendations of this report.

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Forty-seven projects were selected as appropriate for NIST consideration and attention and forwarding to the NIST as high, medium, and low priority projects.

The criteria for the four specific categorization areas are defined below.

High A project for which there is a high level of need by the building community, is appropriate for government funded research, and would be of benefit to the nation. There is an adequate knowledge base to perform research, and it is within the NIST capabilities and charter. It does not compete with private research and is not similar to other recommended research. Research should continue in this area or be initiated as soon as possible.

Medium A project which has a medium level of interest within the building community, and meets most of the other criteria for a high priority project, but cannot be considered in the high category because it does not meet all these criteria. Research should be started on this project as soon as resources become available after work is initiated on those items in the high category list.

Low A project which may be of strong interest to a small segment of the building community, and meets some of the criteria for a high priority project, but not enough to warrant high or medium priority at this time.

Not Applicable (N/A) - A project which cannot be included in any of the other categories for a variety of reasons.

No attempt was made to combine the projects from the four different subject areas into an overall master priority list, therefore each of the four project listings is intended to stand alone. It was noted by at least one committee member from the fire safety community that consideration should be given to prioritizing all projects collectively, to take into account the relative merits of a project in one category verses the projects in the other three. The validity of this approach could be discussed during the development phase of future NIBS/NIST efforts and utilized at that time if appropriate.

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NIBS RECOMMENDATIONS FOR NIST RESEARCH

Conclusions

The following table presents a tabulation of the number of projects received and reviewed by category and priority:

Number of Projects/ By Category

	High	Medium	Low	N/A	Total
Building Environment	12	4	5	10	31
Building Materials	4	1	1	9	15
Building Structures	5	1	5	7	18
Fire Safety	4	3	2	6	15
Total	25	9	13	32	79

The next chapter of this report, Chapter III, contains a narrative rationale of the specific high and medium priority projects which the committee recommends be initiated or expanded as soon as possible. That chapter provides, for each project so categorized, the reason or reasons which are important to the building community for accomplishing the work. It also provides for each project the name and telephone number of the project submitter.

A listing of all the projects submitted and appropriate short committee comments for each are found in Chapter IV, the Project Listing section. The complete listing of these projects is included to show that there are numerous subjects within the building community which require additional research once assets become available to address them, and also to provide subjects for NIST use should the NIST budget allow for the future expansion of research programs.

CHAPTER III FINDINGS AND RECOMMENDATIONS

A. BUILDING ENVIRONMENT
FINDINGS AND RECOMMENDATIONS

The Building Environment subcommittee met in March 1989 at the National Institute of Standards and Technology in Gaithersburg and reviewed each individual project pertaining to building environment. The subcommittee gave each project a priority and felt that sixteen projects warranted special attention by the CBT building environment division.

The subcommittee also felt that several programs should be initiated, expanded or continued by the CBT in the building environment division. The eight programs are delineated below and the high and medium priority projects pertaining to each are listed after each program.

1. Program One - One new project is recommended in this program. The same project was also recommended in 1988. The project is;

   Revise Domestic Water System Sizing Procedures

   The Hunter Curve has been the standard for sizing domestic water systems for hot and cold water supply for buildings in the U.S. The original work on the Hunter Curve was done at an existing CBT facility. Changing to water saving fixtures has resulted in oversized water services. The full benefit of reduced water flow cannot be achieved without basic data to properly size a building water supply system. New curves are needed that are based on the flow rates of today's fixtures.

   Priority: High
   Project: E-1
   Project Proposer: Haig Demergian 213-255-7121

2. Program Two - Three projects were determined to be related to the subject of developing standard tests for measuring heat transfer through building components.

   The goal of this program is to develop standard test methods for measuring heat transfer through building fenestration and combinations of windows, walls, doors, etc. The test methods need to address the combined effects of air infiltration and radiative, conductive and convective heat transfer. Practical interest should be directed at the combined effect of infiltration and heat transfer for the overall building envelope. The test methods need to allow for variations of air pressure, specifically the mass airflow rate as well as the direction of airflow during both the heating and cooling modes of heat transfer.

   Once improved methods for determining thermal performance of windows have been established, then life cycling techniques can be used to produce a rating for labeling the energy efficiency of the windows.

Priority: High
Project: E-2
Project Proposer: David Kehrl Schlegel 716-427-7200

Priority: High
Project: E-9
Project Proposer: Paul R. Achenbach 703-356-3810

Priority: Medium
Project: E-14
Project Proposer: Lou Masonick

3. Program Three - Two projects are recommended in a program dealing with refrigerants.

The goal of this program is to develop thermophysical properties of refrigerants to be used as replacements for fully halogenated chlorofluorocarbon refrigerants. Refrigerant manufacturers need the properties before systems and equipment to utilize potential replacements can be designed and manufactured.

Priority: High
Project: E-13
Project Proposer: William R. Zahn 717-764-4719

Priority: High
Project: E-17
Project Proposer: Herbert T. Gilkey, PE 703-938-0314

4. Program Four - Four projects were determined to be related to the subject of moisture.

Research is ongoing to develop a better understanding of moisture as it relates to the building environment. The CBT is currently working on moisture in wall insulation, which is closely related to two of the projects in this program.

Test methods are needed to evaluate the thermal conductivity and moisture transfer characteristics of building materials. Understanding the moisture flow through the building envelope is only a part of the needed information. Data is needed on how moisture is stored in building structures and furnishings as well as the effects of the release of stored moisture. Finally, an understanding of the transport and moisture capacitance will furnish a basis to develop methods to control moisture and prevent problems of excess or inadequate moisture levels.

Priority: High
Project: E-15
Project Proposer: David E. Knebel 800-641-2830

Priority: High
Project: E-18

Project Proposer: Herbert T. Gilkey, PE 703-938-0514

Priority: High
Project: E-28
Project Proposer: Bion D. Howard 301-249-4000

Priority: High
Project: E-27
Project Proposer: Paul R. Achenbach 703-356-3810

5. Program Five - Indoor Air Quality issues are addressed by completing three projects.

Research is ongoing in the area of indoor air quality and the CBT should continue to develop basic data to aid with the implementation of the revised ASHRAE Standard 62. Of particular interest is the development of data concerning room air distribution using low air motion, a characteristic of variable air volume systems. The CBT should continue to work in the area of evaluation of building ventilation as an effective means to control indoor air quality. A database of ventilation effectiveness will be useful when combined with the work to be done by EPA on emissions from construction materials.

Priority: High
Project: E-19
Project Proposer: Herbert T. Gilkey, PE 703-938-0514

Priority: High
Project: E-22
Project Proposer: Bion D. Howard 301-249-4000

6. Program Six - One project has been recommended in the area of control system protocols.

Research is ongoing at the CBT to develop, evaluate and test communication protocol standards. As more building owners look to using direct digital controls, there is an increasing need to develop a industry-wide common protocol. This work is best done by the CBT with aid by private industry.

Priority: High
Project: E-20
Project Proposer: Herbert T. Gilkey, PE 703-938-0514

7. Program Seven - Two projects are recommended in the area of radiant barriers.

Additional data would be helpful in comparing the use of radiant barriers over a wide range of climatic conditions. Research should address the issue of aging of the radiant barrier. Chief role of the CBT could be in verification of comparison methods between radiant barriers and conventional insulation. Principal testing could continue at Florida Solar Energy Center and by industry.

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Priority: Medium
Project: E-26
Project Proposer: Myron B. Lacher 215-341-7677

Priority: Medium
Project: E-30
Project Proposer: Bion D. Howard 301-249-4000

8. Program Eight - One project has been recommended concerning the fact that the Mean Radiant Temperature (MRT) not always being equal to the Dry Bulb Air Temperature (DBAT) is not factored into the design of buildings and HVAC systems.

Complete useble information is not available that relates the total effects of mean radiant temperature verses dry bulb air temperature on the energy utilization of HVAC systems. Additional understanding of the transient conditions effecting MRT and DBAT would be useful in planning for energy efficient building operation. DOE could be a source of funds for this project.

Priority: Medium
Project: E-10
Project Proposer: Morris L. Markel 716-693-4665

B. BUILDING MATERIALS
FINDINGS AND RECOMMENDATIONS

The materials committee reviewed the input solicited from the building community to categorize and prioritize each submitted project prior to its being forwarded to the Building Materials Division (BMD) of the NIST Center for Building Technology (CBT).

It once again became evident early during the review that perhaps the title "Building Materials" was too limited a term to utilize when describing this subject to the community as a whole. This may have precluded the submission of many projects of importance to the community but not sufficiently described by the term "building materials". A review of the current BMD charter and research agenda also indicated that the focus of the BMD has been on cements, specific roof systems and coatings, which has yielded much benefit to the building community. It does however give rise to the questions: What was the reason for this specific focus? Was it determined by the availability of existing resources verses the identified needs of the building community itself? Prior to soliciting input from the building community in the future, appropriate answers to these questions should be determined. With that input, efforts could be made to more directly involve members of the community into the research of the BMD.

It also is recommended that in future projects a broader view be taken by the BMD for materials research, to assure it includes topics such as the emerging areas of composites, plastics, stress skin panels, and system performance issues as they relate to buildings. A means to accomplish this should be developed and assessed and passed to NIBS early in the project. This would facilitate developing an appropriate set of criteria which the building community could use to evaluate whether they should submit projects as well as what specific projects to submit.

Seventeen proposed projects were reviewed by the committee and five received high or medium priorities. They are specifically addressed in the following paragraphs.

1. High Priority - The following projects are categorized as high priority.

   a. Effect of High Temperatures on Glue Used in Residential Structures.

      Adhesives in general will become a key factor relative to the construction arena in the near future. This is particularly true as stress skin panels are developed for use in both commercial and residential construction. The very nature of stress skins themselves requires the development of new fastening devices. The focus at this time both in industry and academia is in the area of adhesives. Specific issues that will need to be addressed are service life, fire resistance and test protocols to evaluate these new adhesive systems. In addition, the code remifications that occur as a result of using adhesives will need to be addressed. It is our recommendation that this topic could be addressed in either the Materials Division of CBT or in the Center for Fire Research as it relates to fire requirements.

Project Number: M-1
Project Proposer: Edward Vaughn 301-949-9350

b. **Develop Methodology for Predicting Service Life of Glued Laminated Beams and for Condition Assessment of Glued Laminated Beams in the Field When They Show Signs of Delamination.**

This issue is important and is in the same category as outlined for project M-1 dealing with the durability and effectiveness of adhesives in building products. This specific work may be under way at the Forest Products Laboratory and should be under their jurisdiction. If the Building Materials Division takes on the project of looking at adhesives, they should seek collaboration with the Forest Products Laboratory in Missouri.

Project Number: M-8
Project Proposer: Jay Alagia 602-264-1010

c. **Single Ply Membrane Roofing Durability.**

It should be noted that this subject was listed as the Number One priority for the Building Materials Division group in the NIBS report last year. It continues to be a subject requiring attention. Specifically, there is a need to identify in-service applications of the material systems in question. This is required as well as the development of a factorial designed sampling model for the physical properties of interest. The results should then be compared with the accelerated test protocol.

Project Number: M-14
Project Proposer: Anthony D. Chiarello 609-984-5573

d. **Determine Performance of Building Materials and Composites Under Cyclic Wetting and Drying Conditions.**

One segment for this proposed research agenda is extremely important to predict service life of any material. Specifically, one must understand the cyclical and climatic effects of materials in wet and dry environments. As stated by Mr. Bales, the subject is broad. However, we feel it is important that the Building Materials Division focus on this segment for those materials, specifically roofing as this ties back into M-14, and include this work in their service life predictive efforts. An adjunct contact in this work would be the Forest Product Laboratory and the work they are doing with wood materials.

Project Number: M-15
Project Proposer: Erv Bales BTECC

2. Medium Priority - The following project is categorized as medium priority.

a. **NDE Application Methodologies for Wood Structures.**

Nondestructive testing techniques is an area in which the NIST has a significant role. The report that was prepared by R. Valore (see project listing, project M-9) points out the specific areas where NDE testing needs exist and for which specific techniques/procedures should to be developed. This is an area that the subcommittee feels the CBT should emphasize in their research. This would be of specific interest especially during the rehabilitation of structures where materials and system performance must be tested on site without destruction. The CBT should be coordinating with the Forest Products Laboratory as this work continues and should develop a program aimed at those areas that need continued research efforts as outlined in the R. Valore report.

Project Number: M-13
Project Proposer: Robert J. Ross USDA, Forest Products Lab

NIBS RECOMMENDATIONS FOR NIST RESEARCH

C. BUILDING STRUCTURES
FINDINGS AND RECOMMENDATIONS

The recommendations which follow reflect the views of the NIBS Building Structures Subcommittee which was convened on March 2, 1989 to review and provide recommendations and comments for each of the projects submitted for consideration by the building community. After the review, the committee felt that six of the proposed projects would be suitable for further consideration as soon as possible by the Structures Division of the Center for Building Technology (CBT) for their research program. These projects were given high and medium priorities in the project lists in chapter IV of this report and are explained in more detail in this section.

Several of the submitted projects were given high or medium priorities and comments by the subcommittee noting that they are related to existing, ongoing programs at the CBT. This was done to suggest that the concepts are worthy of study and that some of the ideas presented in these proposals could be incorporated by the NIST in their existing projects at the earliest opportunity. Several projects also were added to the list by the subcommittee during the meeting at the CBT. It was felt that ongoing work at the NIST could be expanded to include these important topics.

The following are the specific recommendations for those projects considered to be of a high or medium priority.

1. High Priority - The following five projects have been categorized as high priority and should be initiated as soon as possible.

   a. Non-Destructive Techniques for Constructed Facilities

      The need for improved techniques and methodologies for the condition assessment of existing structures has been increasing rapidly as building remodeling, preservation of historic structures, and structural enhancement for seismic safety, become more prevalent. Relevant Committees of the ASCE, ACI and ASTM are addressing structural condition assessment and rehabilitation and timely informed inputs to their deliberations are important to progress.

      Non-destructive techniques applying state-of-the-art engineering principles, equipment and procedures, can be significant tools for condition assessment, the most promising of which should be selected and further developed for practical application. This project would fit in well with other CBT work in non-destructive testing and condition assessment. Outside funding and other sources of assistance should be explored.

      Project Number: S-1
      Project Proposer: Andrzej Nowak 313-764-9299

b. Connectors Between Concrete and Other Materials

Connecting systems provide the essential interfaces between the structural components being joined. With the increasing practice of strengthening existing facilities and of connecting structural components made of different materials in new structures, a greater understanding of anchoring systems and their behaviors is crucial to good engineering design. Strengthening of structures is a current CBT emphasis area in earthquake engineering with which this project focus is very compatible. Funding from external sources is appropriate especially in dealing with specific or proprietary connector systems and interfacing materials.

Project Number: S-2
Project Proposer: Mel Green 213-374-6424

c. Composite Columns with High-Strength Concrete

1988's high-priority project area on "Behavior and Strength of Composite Frames and Composite Building Frame Interaction" (ref: NIBS Report on Research Recommendations for NIST, 1988, page 15) could be extended to include the study of composite columns using high-strength concretes with f_c's of the order of 15,000 p.s.i. in high-rise structures. Data on shear transfer between steel and concrete, long term durability and creep characteristics of the high-strength concrete, fire resistance, and seismic ductility of the composite system, are needed for the establishment of design guidelines. This effort is an appropriate extension of the 1988 proposed project for which CBT's tri-directional structural testing facility provides unique laboratory support.

Project Number: S-7
Project Proposer: Nestor R. Iwankiw, P.E. 312-670-2400

d. Criteria, Test Methods and Evaluation of Damping Characteristics of Base-Isolation Systems for Structures in Seismic Areas

Base-Isolation systems are finding special applications in systems selection and design of structures subject to seismic forces. There is an urgent need for improved modeling and other engineering data to guide the analysis and design of base-isolation systems. CBT has special research expertise as well as the unique testing facilities to conduct studies in this area.

Project Number: S-17
Project Proposer: M.S. Chawla and Subcommittee

e. Improved Design and Construction Practices to Resist Windstorms

This project deserves national attention so that a facility is made available to conduct the appropriate research. Such research, and pragmatic follow on engineering applications, can help mitigate the building damages windstorms, such as hurricanes and tornadoes cause, which exceed annual average seismic damages. Research in wind characteristics, wind-structure interaction and design practices is needed to mitigate damages and associated economic losses. The CBT currently has work in progress on structural dynamics (swaying of tall building and reviewing applicability of the theory of "chaotic" motion). They have research expertise in this high priority research area, but lack an appropriate wind tunnel research facility. The committee strongly supports the objective for the design and construction of new generation high reliability boundary layer wind tunnel which was a High Priority project in 1988. This project deserves national attention and the successful acquisition of the wind tunnel capability would create a national focus in support of related research activity.

Project Number: S-3
Project Proposer: Kishor C. Mehta 806-742-3476

2. Medium Priority - The following projects has been categorized as medium priority and should be initiated as soon as funding is available.

Evaluation of Performance and Stiffness Contribution of Cladding

It was noted that this topic has been a high priority recommendation of previous NIBS panels. Research data is considered important to improved analysis of cladding frame behavior and to improved design practice.

Project Number: S-18
Project Proposer: Nestor Ivankiv and Subcommittee

NIBS RECOMMENDATIONS FOR NIST RESEARCH

D. FIRE SAFETY
FINDINGS AND RECOMMENDATIONS

The Fire Safety Subcommittee met on February 27, 1989 at the NIST Center for Fire Research to review 15 fire research recommendations. The subcommittee considered 9 of these to be within the research scope appropriate for the Center for Fire Research, and 7 to be in the high or medium category. Subcommittee comments on all of the recommendations received and reviewed are shown in the project listing section of the report.

1. Two general issues appropriate for Center for Fire Research attention surfaced during the subcommittee deliberations. It is recommended that the CFR provide some priority to research that assists in developing solutions to the specific projects mentioned in later paragraphs of this section relating to these general issues. They are as follows;

a. Smoke management in buildings. Extensive computer modeling of the spread of fire and smoke in buildings requires validation through large scale testing. The mechanical engineering profession remains leery of smoke control regulations found in the model codes, in particular for large volume spaces such as atriums and malls. It is noteworthy that CFR testing in a condemned Washington, D.C. hotel is projected for the near future. Such testing can provide valuable data on smoke control in relatively small compartments. Such efforts need necessarily to be carried through to testing in full-scale, large volume spaces to provide validation of the data. All efforts possible should be made to acquire sponsors to support this required research since cold smoke system testing currently used for code compliance is generally recognized to be inadequate.

b. Large sbale fire testing of wall coverings. The contribution wall coverings make to the combustion process remains one of the critical links in predicting fire growth of compartment fires. Current full scale testing at the CFR on the charring of wood wall linings needs to be extended to a variety of characteristic wall materials in order to obtain the required data and determine the optimum proposed fire models.

2. Specific comments on the projects considered to be high and medium priority projects by the subcommittee are presented in this section. It should also be noted that the high priority projects are closely related to the above noted general issues.

a. High Priority

(1) Mechanical Smoke Exhaust Effects on Fire Growth, Fire Spread and Fixed Fire Suppression systems.

The control of smoke associated with a fire, in certain cases can have deleterious side effects and even compound the damage done by the fire, if left to automatic devices. A body of knowledge should be established concerning smoke control that would evolve from small scale testing, through full scale testing and include predictive modelling aspects. With such an approach to the smoke issue, many of the unknowns associated with its control could be utilized within the fire safety and building design community to improve current design and build practices.

Project: F-E5
Project Proposer: Michael E. Dillon 818-449-8948

(2) Smoke Purge - Positive or Negative Pressure.

This project should be considered as part of the general research suggested under paragraph a(1) above for project F-E5.

Project: F-E3
Project Proposer: John C. Clark 612-393-4941

(3) Effectiveness of Engineered Smoke Control Systems in Large Buildings.

This project should be considered as part of the general research suggested under paragraph a(1) above for project F-E5.

Project: F-E13
Project Proposer: Jon Caloger 312-641-5988

(4) Fire Model for Charring Wall Linings in Compartments

Research on this subject is presently in progress at NIST. It should continue and if possible be expanded to include a variety of characteristic wall materials in order to obtain the required data and determine the optimum proposed fire models. With the growth of the use of many types of wall covering or even building cladding, the contribution these materials and their usage configuration make to the combustion process continues to be one of the critical unmeasured and hard to determine factors for predicting fire growth. Attention to this subject will foster the development of more accurate fire prediction techniques.

Project: F-R1
Project Proposer: Dr. E.L. Schaffer 608-264-5668

b. Medium Priority

(1) Investigation of Fire Sprinklers in Non-Sprinklered Existing Buildings By Use of Stand Pipe Risers or Domestic Water Systems.

This project as recommended in essence is asking for research leading to economical methods to retrofit existing buildings with sprinkler systems where sprinklers do not currently exist. The project is not directly applicable to fire research as stated, however it does surface a critical need for the growing rehabilitation sector of the building community and demonstrates the need to investigate water flow requirements for standard sprinkler systems. Work should be done at CFR developing a proposed scope of work for this subject.

Project: F-E6
Project Proposer: James R. Graves 713-978-7000

(2) Effectiveness of Compartmentation in Reducing Fire Hazards.

The study of compartment effectiveness requires full-scale test facilities that NIST does not have operational at this time but which will probably need to be placed into operation in the near future. This will be necessary to extend current fire modeling related to fully-developed fires and consideration of structural fire resistance being conducted at the Portland Cement Association research center. A facility must be available to handle this research either in conjunction with other organizations or funded by them. This needs to be coordinated well with other aspects of fire modeling which need to be considered first.

Project: F-E7
Project Proposer: James P. Hurst 312-966-6200 x 351

(3) Toxic Smoke Hazard of Materials in HVAC Plenums.

This is the second year this project has been included in the special priority listings, since it remains a problem which needs to be addressed. The specific contribution of the materials contained in plenums to the toxic or smoke hazard created by a fire should be a matter of priority research. This could be part of the high priority projects mentioned in paragraph 2a(1) above concerning smoke control in buildings.

Project: F-E8
Project Proposer: Herbert T. Gilkey, PE 703-938-0516

CHAPTER IV PROJECT LISTINGS
SECTION A - BUILDING ENVIRONMENT

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 1	Revise Domestic Cold Water and Hot Water Piping Sizing Procedures.	Review Hunter's curve to calculate the water demand based upon new products and reduced flow plumbing fixtures.	Presently, water systems in buildings are sized based upon data collected over 50 years ago. This leads to oversized pipes which increases the cost of plumbing systems.	Haig Demergian d'Autremont-Helms Assoc. 8311 N. Figueroa St. Los Angeles, CA 90042 213-255-7121.

Subcommittee Comments	Recommended Priority
CBT has facility used for previous Hunter curve work. Completion of this project will reduce building construction cost by reducing pipe sizes.	High

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 2	Conductive/-Radiative/-Convective Heat Transfer Properties of Fenestration Products.	Test methods are required to address air infiltration effects on heat transfer properties at windows & doors. Radiative effects are also required.	To publish to the building and design professional the overall coefficient of heat transfer due to the 3 modes of heat transfer - real world conditions. AAMA & ASTM do not address this.	David Kehrl Schlegal 1555 Jeff Road Rochester, NY '16-427-7200.

Subcommittee Comments	Recommended Priority
This could improve heat flow calculations for windows. Benefit may not justify cost at this time, however project should be scheduled as soon as possible.	High

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 3	Public vs. Private Master Specifications	Do master specifications required by Navy and Corps of Engineer projects provide a higher quality product than projects constructed using private master specifications, eg., AIA's masterspec 2 or CSI'S spectext?	Present use of NAVFAC and COE Master Specifications can require as much as two to four times greater production time than use of a familiar office master. Does this increase in production time provide accompanying increase in "quality"? Data needs to be defined and quantified to provide feedback on quality. Post occupancy reviews researching owner and A/E satisfaction using both public and private master specifications is desperately needed! This has a major impact on how we build our buildings. We see a phase out of Federal Specs that are redundant with ASTM/ANSI or other accepted industry standards. Is it time to consider phasing out NAVFAC and COE standards?	Jason Popelka KZF, Inc. 655 Eden Park Dr. Suite 750 Cincinnati, OH 45202 513-621-6211.

Subcommittee Comments	Recommended Priority
This is a project that should be undertaken by CSI or AIA. CRT is working on the process of developing NAVFAC guide specs.	NA

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 4	Infiltration thru Industrial Type Windows in Multistory Industrial Buildings.	Information is available for infiltration in 1, 2 and 3 story residential buildings for retrofit work, similar info is required for industrial buildings.	Infiltration rate, for CFM/Lin.Ft. of crack for various types of windows and various wind velocities. Heights up to ten stories should be considered. To the best of our knowledge such information is not available. Reliable information would result in more efficient, cost efficient design.	Herbert Reich, P. E. HH Reich Consulting Engrs 8 E. Mall Plaza Carnegie, PA 15106 412-279-8323.

Subcommittee Comments	Recommended Priority
This project would be better handled by field tests of existing conditions, since this involves building retrofit.	NA

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 5	Shut-off of Building Services at Commencement of Earthquakes. Detectors in ventilating systems for toxic materials.	Determine the vibration conditions which would cause electrical, gas service, or other service failures during a quake that could hazard safety and health of persons who would be trapped in a building. Certain gases are potential hazards in combustion activated heating systems and internally fuel fired transport equipment. A simple visual detector to serve as a visual alarm is required to solve heat exchanger or exhaust system problems.	Reliable measurement of quakes which could forecast the problem; Reliable means of interrupting the services without provision of the normal forms of energy which enter the building; Reliable means of maintaining each service so that the shutting off of the service does not generate a hazard by itself through power failure, flooding of basements, etc.	J. Klassen Retired 942 Dresden Cr. Ottawa Canada K2b551 613-820-7828.

Subcommittee Comments	Recommended Priority
There is a need for design recommendations dealing with mechanical and electrical equipment during earthquakes. CBT lacks the facility to do this project. Work would be better accomplished by National Center for Engineering Research at State University of New York at Buffalo.	NA

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 8	Energy Efficient Building System (Residential).	Practical solutions to the problem of designing an economic (low cost) home which satisfies the criteria of energy efficiency, comfort, aesthetics, and indoor air quality.	Industry acceptance of "Energy Efficient" Buildings has been inhibited by increasing costs of construction associated with high insulation levels and expensive HVAC systems. Resultant low energy consumption is often not sufficient incentive for high initial capital outlay. Resale value of "Enhanced" property might not reflect additional expense. Practical integrated systems using sustainable technology could offer the solution -(s) that society needs to properly address future concerns with diminishing resources, increasing energy costs, reduced availability of urban area and environmental damage.	Ralph D. McGrath Fiberglas Canada Inc. P.O. Box 3049 Sarnia, Ontario N7T7X4 519-336-5070.

Subcommittee Comments	Recommended Priority
The CBT is not equipped to do design optimization. This might be better handled by the National Home Builders Association.	NA

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 7	Man - Building Interface.	We have made buildings and building systems too complex for the real world to understand and operate effectively. The designers and operators must have some common denominator to achieve desired results.	The gap between designer and operator must be addressed through better communications. A good designer must understand the limitations of operators and at the same time the operators must improve their skills. At this point the gap is very wide resulting in poor building performance. Research should be directed to improved communication means and building commissioning - understanding the limitations of the real world.	George Jackins, P.E. Engineering Resource Group, Inc. P.O. Box 380687 Birmingham, AL 35236 205-985-9090.

Subcommittee Comments	Recommended Priority
This is important work, CBT has prepared a major manual for GSA. This looks more like education/work with AIA, ASHRAE or NSPE. CBT could offer existing data.	NA

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 8	Relative Effect of Chlorofluorocarbons on The Atmosphere Compared To Gases Emitted From Internal Combustion Engines and Oil Refineries.	To establish a system of priorities to diminish the effects of harmful gases fouling our atmosphere, with emphasis on central business districts.	The negative gap appears to be the monitoring and analyses of the products of combustion fouling the atmosphere.	James N. Keen Consulting Engrs of British Columbia 800-890 West Pender St. Vancouver, B.C., Canad V6C 1K4.

Subcommittee Comments	Recommended Priority
CBT is not equipped to do this work. Task is more exterior environmental. This work could be better done by NOAA or EPA.	NA

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 9	Laboratory Measurement of Heat Transfer across Building Walls under Simultaneous Temperature and Air Pressure Differences.	A. Develop an ASTM test procedure to measure the "effective conductance" of full scale building wall specimens, including windows and doors, under an imposed temperature and air pressure difference with temperature and air pressure in the same or opposing directions. B. The procedure shall provide a measurement of the mass air flow rate. C. Locations of the air leaks shall be identified insofar as possible.	Air leakage through walls constitutes a significant portion of the heat transmission in most buildings. Present air infiltration measurement methods involve whole buildings exposed to natural outdoor conditions or to a pressure difference imposed on the whole building by a fan. Present technology does not provide a direct measurement of the effect of air leakage on any specific building element. The proposed test procedure would provide a good measurement of how much air leakage degrades the thermal resistance of full scale walls.	Paul R. Achenbach BTECC 1322 Kurtz Road, McLean Va 22101 703-356-3810.

Subcommittee Comments	Recommended Priority
The work is ongoing at CBT. Work should be continued to provide an understanding of the interrelationship of air, heat and moisture transfer through the building envelope. This work is related to projects M-12 and M-15.	High

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 10	Effect on Energy Utilization of the Built Environment by Using Radiancy for Occupant Comfort During Transient Conditions.	The estimated energy utilization of bldgs and their HVAC systems is presently determined for steady state indoor design conditions based on the Dry-Bulb Air Temperature (DBAT). This procedure assumes mean Radiant Temperature (MRT) is equal to DBAT. Most bldgs. use transient conditions to provide a thermally acceptable environment. Under transient conditions the MRT is normally not equal to the DBAT. Therefore, the design procedures to incorporate the effect that higher or lower MRT's have on building energy performance and their HVAC systems is important.	1. Determine the effect of heat transfer through components of the building envelope for various indoor surface radiant temperatures and identified air temperature differences. 2. Establish a procedure for determining the DBAT in a building where an acceptable environment for occupants is established recognizing the MRT in the occupied space. 3. Develop a model that determines energy requirements for the buildings HVAC system recognizing the effect and procedure of item #1 and #2 above.	Morris L. Markel M.L. Markel-Consultant 908 Niagara Falls Blvd. North Tonawanda, NY 14120 716-[illegible].

Subcommittee Comments	Recommended Priority
The committee agrees that this project is needed. It is possible that DOE or ASHRAE might want to take on this work. The CBT has energy simulation software available, but is not now set-up to do the testing to verify the proposed model. Information from this type project would be very useful for analyzing occupant comfort.	Medium

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 11	Enhance BTECC /NIBS Interaction and Input to the NAHB/NRC Building Research Agenda.	Better Industry - Federal coordination.	Dialogue with NAHB/NRC on National Research Agenda is recommended for enhancement.	Bion D. Howard NAHB 400 Prince George's Blvd. Upper Marlboro, MD 20772 301-249-4000.

Subcommittee Comments

We believe that lines of communication are available through members of the CBT staff who are members of BTECC.

Recommended Priority

NA

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 12	Format and Methodology For Energy Budgets.	While there are a wide variety of techniques published for the determination of energy budgets and conduct of energy audits, there are no generally agreed upon methods for accomplishing and utilizing this information effectively.	Information is required for determining how audits should be conducted and what the norms are for various components of energy use in buildings. This information will allow more reasonable and accurate determination of modifications to energy systems in buildings to improve energy performance.	L.G. Spielvogel, P.E. ASHRAE TC 9.6 Wyncote House Wyncote, PA 19095 215-887-5600.

Subcommittee Comments

We agree that work on standardizing energy budgets is important. However, this project would be better suited for ASHRAE, DOE and/or ASTM, since it concerns standards development.

Recommended Priority

NA

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 13	Thermophysical Properties of CFC Replacement Refrigerants.	Obtain experimental data on properties needed to permit heat transfer calculations for fluids and/or mixtures being recommended as replacements for CFCs R11 & R12.	To properly evaluate the effect on system performance, design, and energy utilization in current or new systems it is necessary to be able to calculate the change in heat transfer with the new refrigerants when boiling, condensing and in single phase operation. Properties needed are: thermal conductivity (vapor & liquid), viscosity (vapor & liquid), surface tension and specific heat (vapor & liquid). Current fluids of interest are: R123 and R134a among others.	William R. Zahn ASHRAE 2283 Linden Road York, PA 17404 717-764-4719.

Subcommittee Comments	Recommended Priority
This is an ongoing CBT project and should be continued.	High

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 14	Window Labeling for Energy Efficiency and Cost Life Cycle.	Evaluate the various methods available for determining cost vs aging (life cycle), and apply this information as one or two numbers to a window label.	There are many methods available to calculate "Products Age Life". We need a uniform method that is acceptable to industry and understood by the consumer. In order to get an age life cycle number(s) we need an acceptable means to calculate energy savings. ASHRAE and DOE are funding LBL to come up with some of this information.	Lou Masonick ASHRAE TC 4.5 (3M Company) 3M Center, Bldg 207-1-08 St. Paul, Mn 55113.

Subcommittee Comments	Recommended Priority
This project is of interest and could fit in with other labeling programs if DOE is interested in providing funding. Personnel with experience with window life cycle cost are available at NIST although not presently assigned to CBT. We do not feel that it would be practical to do product age life calculations, as this is not being done for other products. The CBT could develop test methods and ASTM might develop a standard. Labeling would be the responsibility of the Federal Trade Commission.	Medium

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 15	Effect of Building Moisture Capacitance on Air Conditioning Use.	Assess the moisture storage capacitance of conventional building structures and furnishings. Develop methodology for incorporating the effects of moisture storage and release on A/C use.	The effect of moisture storage and release has been neglected in analyzing building energy performance. With the use of ice storage systems in a low humidity environment, the impact appears to be more important. Little data is currently available.	David E. Knebel Paul Miller Company 1600 Wesy Phelps Springfield, MO 65801 800-841-2830.

Subcommittee Comments	Recommended Priority
This project is of interest and fits with ongoing projects at CBT. This investigation would provide information to aid in the evaluation of natural ventilation systems, conventional HVAC systems, and air purging of buildings for dilution of indoor air contaminants.	High

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 16	Measurement of the Thermal Performance of Wall Sections with Thermal Bridges.	Many curtain wall designs include thermal bridges that transmit significant amounts of energy between the controlled interior environment and the outdoors. Several models are available but none have been verified with laboratory measurement.	Data in wall sections that include thermal bridges are needed for the ASHRAE Handbook of Fundamentals, 1984 edition. At present there is data for only one manufacturer. An expanded data base on given wall sections is needed. The wall sections tested should include representative designs for curtain walls.	William W. Seaton ASHRAE 1791 Tullie Circle, NE Atlanta, Georgia 30329 404-636-8400.

Subcommittee Comments	Recommended Priority
We agree that this work would be valuable; however industry should be able to do this type of testing using techniques developed by CBT.	Low

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 17	Thermodynamic and Transport Properties of Fluorocarbon Refrigerants.	The production/availability of fully halogenated CFC's refrigerants are being reduced. Potential substitutes have been identified. Their thermodynamic and transport properties must be known before systems and equipment to utilize them can be designed and manufactured.	Thermodynamic and transport properties of fluorocarbon refrigerants and refrigerant mixtures that are not fully halogenated.	Herbert T. Gilkey, PE Engineering Consultant 2808 E. Meredith Drive Vienna, VA 22181-4039 703-938-0514.

Subcommittee Comments	Recommended Priority
This is an ongoing CBT project and should be continued.	High

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 18	Control of Moisture in Buildings and Building Components.	Excess building moisture can result in materials deteriorating and create a breeding/feeding ground for mold and other adverse organisms. Adequate humidity is also required for proper equipment operation and occupant comfort.	Moisture retarding properties of films and surfacing materials; identification of additives or admixtures that slow or prevent moisture damage to building materials.	Herbert T. Gilkey, PE Engineering Consultant 2808 E. Meredith Drive Vienna, VA 22181-4039 703-938-0514.

Subcommittee Comments	Recommended Priority
With interest in increasing outside air to solve indoor air quality issues, excess moisture can occur in buildings. The added ventilation will dilute indoor pollutants, but could allow conditions that allow the increased growth of molds, etc. This project would provide information to aid in controlling moisture problems.	High

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 19	Air Distribution to Improve Room-Air Circulation at Desk Level.	Some IAQ complaints state the environment is stuffy while air temperature is in the comfort range. Low air motion is found when high levels of CO_2 are measured. Conditioned air is introduced through outlets that provide inadequate vertical throw or are controlled by thermostats that cause the dampers of variable air volume boxes to modulate.	Air velocity and temperature data measured in a space in which different supply-air at various temperatures and velocities is delivered through outlets of different types. There is much literature on room-air distribution research, but a great many systems with the problems described above have been and are being designed and installed in offices.	Herbert T. Gilkey, PE Engineering Consultant 2806 E. Meredith Drive Vienna, VA 22181-4039 703-938-0514.

Subcommittee Comments	Recommended Priority
This project is valuable and of interest and can be done with present facilities.	High

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 20	Protocol for Communication between Control Systems.	Control systems for functions within a bldg are frequently unable to communicate, e.g., an engineered smoke control system usually takes control of certain dampers/fans that are part of the building air conditioning system. The controls must be able to communicate.	There should be developed a protocol that control system and other designers can observe to assure communication between control systems.	Herbert T. Gilkey, PE Engineering Consultant 2806 E. Meredith Drive Vienna, VA 22181-4039 703-938-0514.

Subcommittee Comments	Recommended Priority
This is an ongoing project of CBT and should be continued.	High

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 21	Commercial Building Temperature Recovery.	To determine experimentally the additional capacity required for heating/cooling, allowing night and weekend setback and shutoff, and still provide comfort at the beginning of occupancy within a reasonable length of time.	Experimental data are required in various types of buildings with various construction materials using various types of heating and air conditioning systems to relate recovery time to equipment capacity and indoor temperatures.	L.G. Spielvogel, PE ASHRAE TC 9.8 Wyncote House Wyncote, PA 19095 215-887-5650.

Subcommittee Comments	Recommended Priority
This study would be of interest, but is in the area of field investigation rather than laboratory investigation. The CBT is not chartered to do this type of work.	Low

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 22	Indoor Ventilation Effectiveness and Air Quality Issues.	Ventilation may be an effective solution to IAQ problem once source strengths of pollutants are controlled. To be most effective indoor spaces must be well mixed.	Review ventilation effectiveness mixing issues, interactions with heating and cooling systems, etc. with the objective of quantifying ventilation effectiveness for enhancing IAQ in typical indoor spaces. Derive design guidelines from an IAQ ventilation data base for both residential and commercial buildings.	Bion D. Howard NAHB 400 Prince Georges Blvd. Upper Marlboro, MD 20772 301-249-4000.

Subcommittee Comments	Recommended Priority
This is an ongoing project of the CBT. It is important work which should be continued.	High

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E -23	Sources of Indoor pollution - Construction Materials vs. Building Contents, and Releases From Services or Occupants.	The emissions of toxics from construction materials can reduce over time after project completion, however occupants bring in of variety of materials and items which themselves liberate pollutants in services or occupation.	A more complete review of the emissions from occupant sources is required since current non-radon IAQ research focuses on construction materials, thereby missing a major part of the problem in all building types. A program to better characterize occupant sourced IAQ problems is needed to study the issue and gather pollution concentration data in existing verses new buildings.	Bion D. Howard NAHB 400 Prince Georges Blvd. Upper Marlboro, MD 20772 301-249-4000.

Subcommittee Comments	Recommended Priority
This is an ongoing project of the EPA. Most of this work is being done at the EPA facility in Research Triangle Park, N.C.	Low

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 24	Leakage of Radon Bearing Soil Gases into Buildings Through Cracks in Concrete Slabs.		I suggest that a fundamental element of the solution to radon infiltration into buildings would to design concrete slabs as integrity barriers. Obviously, this requires the development of systems with reduced cracking potential which can be successfully implemented in the field.	Richard W. Dixon, P.E. State of Florida Department of Community Affairs 2740 Centerview Drive Tallahassee, FL 32399.

Subcommittee Comments	Recommended Priority
We believe methods exist to control concrete cracks.	Low

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 25	Need for Backflow Preventers on Fire Service Lines.	Most health depts are requiring expensive backflow preventers on fire service lines which require 10 psif pressure loss. Are they effective and really needed?	Is there evidence of backflow from fire system piping causing disease? Are we spending a lot of money and energy needlessly? Is this requirement in the interest of the manufacturer or the public?	Edward Maybeck P.E. Maybeck, Bucher & Volland 302 North Goodman Street Rochester, New York 14607 716-473-7330.

Subcommittee Comments	Recommended Priority
Backflow preventers are required by the Federal Clean Water Act. Perhaps AWWS would be a suitable agency for research.	. NA

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 26	Radiant Barrier System (RBS) Thermal Performance.	A simple way to compare performance of radiant barrier systems (RBS) with other insulation types (effective R-value) is needed to enable building designers to determine the most cost effective ceiling insulation systems for different locations and constructions.	RBS performance is dependent on climatic conditions. A computer program that takes into account local climate factors e.g. annual temperature and solar radiation, is needed. The program would need to be validated by field tests. Oak Ridge National Laboratory has done field work and made progress in developing a computer program, but lack of attic ventilation data limits the value of the work. Can NIST build on the present work to achieve the goal of an effective R-value for RBS?	Myron B. Lecher Certainteed Corp. 750 E. Swedesford Rd. Valley Forge, PA 19482 215-341-7877. Kenneth D. Mentzer Mineral Insul. Manuf. 1420 King Street Alexandria, VA 22314 703-684-0084.

Subcommittee Comments	Recommended Priority
The project has merit and national interest. Regional work has been done at the Florida Solar Energy Center (FSEC) and the Oak Ridge National Laboratory (Contact Ken Wilkes). Additional R&D may be planned at these institutions.	Medium

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 27	Thermophysical Properties of Concrete and Concrete Masonry Materials.	a) Develop steady state test methods for determining the thermal properties (thermal conductivity, specific heat and thermal diffusivity) of concrete materials, including the effect of moisture and, b) Perform analytical and experimental evaluation of the effects of constituent materials on the thermophysical properties.	Concrete and concrete masonry will continue to be used in most types of building construction. There is no standard hot plate method for measuring thermal conductivity nor a standard technique to ensure consistent results at different laboratories. Present methods do not adequately account for the presence of moisture.	Paul R. Achenbach BTECC 1322 Kurtz Road McLean, VA 22101 703-356-3810.

Subcommittee Comments	Recommended Priority
Facilities at CBT are clearly those needed for this work. Results would provide test methods that could standardize testing by industry.	High

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 28	Evaluate Reductions in R-Value due to Moisture in Wall and Ceiling Insulation.	More data is needed on the impacts of moisture on fibrous and cellulosic building insulations performance, from credible independent source.	Moisture is known to increase the conductance of thermal insulation. Fibrous and cellulosic materials have different properties of moisture uptake and change in conductivity. Insulations should be sampled in the field under a variety of conditions, returned intact to the laboratory and measured for moisture content and thermal properties. Field gathered specimens measured in the lab will add to our knowledge on insulation performance.	Bion D. Howard NAHB 400 Prince Georges Blvd Upper Marlboro, MD 20772 301-249-4000.

Subcommittee Comments — **Recommended Priority**

CBT currently working on moisture in wall insulation which should continue. A computer model is being developed. The model should be validated using experience data. This work should also have input from the Building Materials Division. — High

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 29	Evaluate Integral Concrete Block Insulation Systems (ICBIS).	Most ICBIS manufacturers use calculations of U and R to market their products. Integral insulation creates special heat transfer computation problems.	Hot box testing and enhanced modeling capabilities for the generic ICBIS configurations should continue. These systems can be used to improve the thermal performance of foundations, while providing inherent protection of the insulating materials. Need measured data on and under calibrated Hot Box conditions, and further refinement of computer models.	Bion D. Howard NAHB 400 Prince Georges Blvd. Upper Marlboro, MD 20772 301-249-4000.

Subcommittee Comments — **Recommended Priority**

Standard test methods exist for industry to do insulation in concrete block test. CBT has tested this type of wall in the past. — Low

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV A - Building Environment

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 30	Aging of Radiant Barrier Materials and Systems (RBS).	An increase in RBS emissivity reduces the effectiveness of their heat transfer properties. Most RBS are marketed based on tested E when new; aged E values and hence performance reduction potential needs to be tested.	Obtain and test aged RBS materials for emissivity in the long wave. Compare aged E with tested "new" E where available. Develop accelerated aging test methods and specs for RBS and submit to ASTM for review and approval. Create independent RBS performance data base.	Bion D. Howard NAHB 400 Prince George Blvd. Upper Marlboro, MD 20772 301-249-4000.

Subcommittee Comments	Recommended Priority
See project E-28; this has interest.	Medium

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
E - 31	In-Situ-R-Value Measurement.	Development of a year round method of determining effective in-situ R-values in a minimal amount of time (less than 1 hour or so).		Sharon Semanovich Allen App. Infrared Tech. #1, Box 533A Highstown ,NJ 08520.

Subcommittee Comments	Recommended Priority
Purpose and required data for the proposed investigation is not clear. What data is required?	NA

SECTION B -BUILDING MATERIALS

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
W - 1	Effect of High Temperatures on Glue Used in Residential Structures.	1. The effect on built-up structural members. 2. The effect upon composite panels (not plywood) that are made from wood chips, sawdust, etc.	1. How long does the glue have the capacity of acting as a structural fastener at high temperatures? 2. How quickly do vertical glue panels resist high temperatures?	Edward Vaughn 3925 Plyers Mill Rd Kensington, MD 2089 301-949-9350.

Subcommittee Comments

Adhesives in general will become a key area relative to the construction arena in the near future. This is particularly true as stress panels are developed for use in both commercial and residential construction. By the very nature of stress skins themselves, new fastening devices will need to be developed.

Recommended Priority

High

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
W - 2	Survey Industrial Countries To Learn Their Building Techniques. Learn the Way They Are Taking Business Away From the U.S.A.	Recover the housing market and expand it. Get back markets lost to overseas manufacturers and get into their markets.	The data, research and development, needed will not be known until the survey is complete.	Charles F. Gilbo, Consultant 1820 Westcott Dr. Lancaster, PA 17603 717-392-0520.

Subcommittee Comments

This is a policy issue and is not one that can be addressed in this forum. This issue should be referred to Carle Wills.

Recommended Priority

N/A

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
W - 3	In-Situ-R-Value Measurement.	Development of a year round method of determining effective In-Situ R-Values in a minimal amount of time (less than 1 hour or so).		Sharon Semanovich Allen Applied Infrared Tech. #1, Box 533A Hightstown, NJ 08520.

Subcommittee Comments

This issue should be reviewed by the Building Environment Division. Specifically, the Oak Ridge National Laboratory (Dave Mackelroy) is doing work on R-value measurement. It is the Committee's recommendation that this should be a private sector project.

Recommended Priority

N/A

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
W - 4	Prediction of One-Day Strength of Heat-Cured Concrete Based On Time-Temp Curve.	Concrete for Pretensioned Bridge Girders: Many State D.O.T.s require a fixed amount of heat curing time (say 20 hours, in Pennsylvania) before releasing beams from steel forms. This is costly and unjustified. Research is needed to develop a strong correlation between the strength of heat cured concrete and the area under the Time-Temperature curve similar to previous Carino's research.	The 1-day strength of steam-cured concrete increases as the number of hours increase. N. Carino's research showed that strength prediction of normal-cure concrete can be found from the area under the Time-Temperature curve. (the precast industry). The same method could be used in for heat-cured concrete typically subject to 12-20 hours of steam curing. What is needed is a cooperative project between CBT and precasters who volunteer their records of T/T curves and corresponding 1-day strengths. Part of the research could be done in CBT labs and the rest at the producer's plants. Several precast producers have expressed interest in the idea.	Dr. Alex Aswad Penn State University Olmsted Bldg, W-281 Middletown, PA 17057 717-948-6182.

Subcommittee Comments

This is a problem that appears to be aimed at a very small segment of the concrete industry. It is the Committee's recommendation that industry representatives interact with CBT to seek guidance on work to be done collaboratively with the industry.

Recommended Priority

N/A

Section IV B - Building Materials

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
M - 5	Single Ply Membrane Roofing.	Selecting the appropriate roofing material for a project based on the project's use, geographic location, structural composition, etc.	The many different available membrane compositions (PVC, EPDM, etc.), thicknesses, and chemical properties have become blurred in the specifier's mind. A more organized matrix of selection choices must be provided to avoid selecting a material based on advertiser ads rather than a rational decision based on local conditions, project requirements, building construction, cost effectiveness & life cycle cost analysis.	Marvin J. Canter, AIA 800 S Hamilton Dr. Fairfax, VA 22031 703-280-2287.

Subcommittee Comments

An organized matrix of selection choices is presently available in the "Roofing Material Guide" published by the National Roofing Contractors Association. It should be noted that this area was listed as the number 1 priority for the Building Materials Division group in the NIBS report last year.

Recommended Priority

N/A

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
M - 6	Shear Capacity of Gypsum Board and Plywood, Screw Attached to Steel Stud Framing.	Roof and floor diaphragm capacities. Shear wall capacities. Classification as flexible, semi-rigid or rigid diaphragms.	-Screw diameter -Screw spacing -Stud/Joist spacing -Plywood thickness/quality -Gypsum board thickness/quality -Edge Distances -Panel layouts -Cyclic Loading	Ron Brenner Reed Jones Christoffersen, Inc. 3838 N.Central Ave. Phoenix, AZ 85012 602-274-1395.

Subcommittee Comments

This is information that perhaps already resides with the manufacturers. The manufacturers should supply this information. Specifically, USG can supply information to the proposer and a third party person would be the UL: testing organization.

Recommended Priority

N/A

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV B - Building Materials

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
M - 7	Develop Methodology for predicting service life of Glued Laminated Beams and for their Condition Assessment of in the field when they show signs of Delamination.	We have encountered delaminated beams after a few months erection time, perhaps due to change in humidity when construction of a building is partially completed. We have also encountered severe - beam cracking after ten to fifteen years in glued laminated beams. Needed research will provide a methodology to assess and predict such problems.	Technology to predict long term behavior of glued finger joints in tension does not exist. These joints will fail during first twenty years and cause the structure to collapse. During construction, delamination partially thru the beam thickness is often encountered. Technology today does not permit the assessment of this condition. Wrong assessment without proper methodology can result in economical hardship, delays or unsafe structures.	Jay Alagia Alagia Engrs Group 1010 E. Missouri Phoenix, AZ 85014 602-264-1010.

Subcommittee Comments	Recommended Priority
This issue falls under the same category as that outlined in M-1 dealing with the durability and effectiveness of adhesives in building products.	High

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV B - Building Materials

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
M - 8	Thermophysical Properties of Concrecte and Concrete Masonry Materials.	a) Develop steady state test methods for determining the thermal properties (thermal conductivity, specific heat and thermal diffusivity) of concrete materials, including the effect of moisture and; b) Perform analytical and experimental evaluation of the effects of constituent materials on the thermophysical properties.	Concrete and concrete masonry will continue to be used in most types of building construction. There is no standard hot plate method for measuring thermal conductivity nor a standard technique to ensure consistent results at different laboratories. Present methods do not adequately account for the presence of moisture.	Paul R. Achenbach BTECC 1322 Kurtz Road McLean, VA 22101 703-356-2810.

Subcommittee Comments	Recommended Priority
R. Valore from the Building Materials Development group has just submitted a report to the ACI for publication. The Portland Cement Association and Lime Industry are all interested in this area and it is an important problem. It should be noted that Oak Ridge National Laboratory is doing work in this related area as well. A person in that group is Dave Mackelroy. This may be an issue for the Building Environmental Division to look at since an unbiased test protocol needs to be developed and provided as a base for a standard in this area.	Low

Section IV B - Building Materials

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
N - 9	Durability of Exterior Wall Insulation & Finish Systems such as that manufactured by DRYVIT.	Research is needed to determine if this type of exterior finish will stand the test of time. Will this finish withstand the harmful effects of pollution, acid rain and other severe environmental conditions?	How long will this finish system be effective in protecting the building's interior from the exterior environment. How long will the system last before repairs are required to maintain water tightness? A number of new renovation projects now utilize this system. A negative financial impact could develop if the system fails or becomes a maintenance problem.	Anthony D. Chiarello Division of Bldg & Constr. (DBC) 50 Barrack St. - CN235 Trenton, N.J. 08625.

Subcommittee Comments	Recommended Priority
This is an industry issue that should be addressed by them. NIST can provide guidelines.	N/A

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
N - 10	Enhance BTECC/NIBS interaction with input to the NAHB/NRC Building Research Agenda.	Better Industry - Federal Coordination.	Dialog with NAHB/NRC on National Research Agenda is recommended for enhancement. (not a "data" or "project" need per-se).	Bion D. Howard NAHB 400 Prince Georges Blvd Up'r Marlboro, MD 20773 301-249-4000.

Subcommittee Comments	Recommended Priority
This is an internal policy issue with NIBS and NIST and can not be resolved in this forum.	N/A

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV B - Building Materials

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
W - 11	NDE Application Methodologies for Wood Structures.	The wood products community has devoted considerable effort to developing NDE techniques for in-place evaluation of wood structures. No consistent methodologies exist on how to utilize the developed techniques. Research aimed at providing such methodologies would significantly advance the use of NDE techniques in wood structures condition assessment.		Robert J. Ross USDA, Forest Products Lab. One Gifford Pinchot Dr. Madison, WI 53705.

Subcommittee Comments

Nondestructive testing techniques is an area in which NIST has a roll to play. Here again the report that was prepared by R. Valore as mentioned under item W-8 points out the areas where NDE testing still needs to be developed. This is an area in which the Committee feels NIST should continue their work.

Recommended Priority

Medium

Section IV B - Building Materials

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
M - 12	Single Ply Membrane Roofing Durability.	The life of single ply membrane roofs does not appear in many instances, to be very long compared to built-up asphalt roofs, before leaks develop.	Seams in materials used for single ply roofing systems, especially adhesive seams, have a tendency to break-down quickly, permitting leaks to develop. Flashing systems and methods of finishing edge conditions do not always work. Although these problems may be a function of the method by which an individual contractor installs a system, investigation is necessary to assure the materials and bonds are up to size.	Anthony D. Chiarello Division of Bldg & Constr. (DBC) 50 Barrack St., CN235 Trenton, N.J. 08625 609-984-5573.

Subcommittee Comments	Recommended Priority
It should be noted that this topic was listed as the Number 1 priority for the Building Materials Division group in the NIBS report last year.	High

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
M - 13	Determine Performance of Building Materials and Composites Under Cyclic Wetting and Drying Conditions.	There is a need to evaluate the effect of climate induced daily, seasonal, and annual cycles of wetting and drying of building materials and composites on in-situ performance.	The data on materials and composite properties and characteristics could be used in the development of models to evaluate attic spaces, closed spaces, and wall space that perform with cyclic boundary conditions. A standard test procedure to test underdynamic moisture conditions would be an additional result.	Erv Bales BTECC

Subcommittee Comments	Recommended Priority
The committee feels it is important that the Building Materials Division focus on those materials, specifically roofing as this relates to reduction in R-Value due to moisture in insulation, and include the results in their work in their service life predictive efforts.	High

Section IV B - Building Materials

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
N - 14	Durability of foam in place roofing.	Due to the thin coating applied to protect the styrofoam insulation and the moisture absorbing nature of the material, what can be done to enhance the durability of the material?	Since the thin coating applied to protect the insulated roof is easily torn and the insulation absorbs moisture when any is permitted to penetrate, are there methods by which this system can be constructed which can still provide the same benefits yet be of a much more durable nature?	Anthony D. Chiarello Division of Bldg & Constr. (DBC) 50 Barrack St., CN235 Trenton, N.J. 08625 609-984-5573.

Subcommittee Comments	Recommended Priority
This is not a research topic but a product issue that should be handled directly by the manufacturers.	N/A

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
N - 15	Aesthetic Effects of the Application of Silicone Resins, Silanes & Siloxanes on Red Brick Masonry as Water Repellent.	Research has been done regarding the effective water repellency of these products. No thorough study exists addressing the negative visual effects some of these products produce on bldgs. in the form of an off-white haze or residue.	The haze or residue is difficult if not impossible to remove and has been a source of complaints from bldg. owners, architects, engineers, general contractors and product suppliers. Causes include inadequate surface cleaning (muriatic acid), bad application techniques (temp., weather), dust accumulation, acid rain, faulty product, etc. This is a problem not limited to one geographical area of the US. It has occurred on red brick bldgs. when these waterproofing products were applied.	Cole Presthus Talbott Engineers 7 SE. 97 AVE Portland, OR 97216 503-256-3652.

Subcommittee Comments	Recommended Priority
Standards should be addressed by the Exterior Coatings Industry.	N/A

SECTION C - BUILDING STRUCTURES

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S - 1	Non-Destructive Techniques for Constructed Facilities	To evaluate the state of existing structures.	Use the state-of-the-art equipment and procedures available in other branches of engineering (electronics, optical methods, acoustics, sensors).	Andrzej Nowak Univ. of Michigan Civil Eng. 2370 GG Brown Ann Arbor, Mi 48109 313-764-9299.

Subcommittee Comments	Recommended Priority
Non-destructive testing is a current project area at CBT. This project fits right in. Work will support committees on condition assessment and rehabilitation of structures; i.e. ASCE, ACI, ASTEM E-6. Seeking external sponsorship of studies highly encouraged.	High

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S - 2	Connectors Between Concrete and Other Materials.	New higher strength, concrete "drilled in" anchors are needed. Research in the U.S. has been by manufacturers with modest strength improvements. Europeans are far ahead because there has been government supported research.	Methods, test data, installation and field verification methods. Basic research is needed too.	Mel Green Melvyn Green & Assoc. 1145 Artesia Blvd. #204 Manhattan Bc., CA 90266 213-374-8424.

Subcommittee Comments	Recommended Priorities
Need for project is well-established. Strengthening of structures is a current CBT emphasis area in earthquake engineering (mainly concrete structures and shearing tests). Much more work relating to "anchoring systems" needed, and increased funding from external sources necessary for study of special material and proprietary systems. Work will support contribution to standards committees (e.g. ACI Anchors Committee).	High

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV C - Building Structures

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S - 3	Improved Design and Construction Practices to Resist Windstorms.	Windstorms such as hurricanes and tornadoes cause building damages that exceed annual average seismic damages. Research in wind characteristics, wind-structure interaction and design practices is needed - to mitigate damages and associated economic losses. Technology gap exists in the knowledge of wind characteristics for hurricanes and tornadoes and the effects of these winds on buildings/ structures and alternative designs.	Specifically, following items should be pursued: (1) topographic effects on wind, (2) wind turbulence in hurricanes and tornadoes, (3) alternative connections to mitigate damages, (4) effects of wind on building roofs, (5) serviceability criteria for high-rise buildings, and (6) improvement in wind tunnel technology.	Kishor C. Mehta Texas Tech University Box 4089 Lubbock, TX 79409 806-742-3476

Subcommittee Comments	Recommended Priority
This project deserves national attention. The CBT currently has work in progress on structural dynamics (swaying of tall building and reviewing applicability of "chaotic" motions). This is a high priority research area in which the CBT has research expertise but lacks an appropriate wind tunnel facility. The committee strongly supports the objective of design and construction of new generation high reliability boundary layer wind tunnel (High Priority 1988).	High

Section IV C - Building Structures

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S - 4	Diaphragm Capacity For Roof Systems Composed of Steel Bar Joists, Hat Section Sub-Purlins, and Standing Seam Metal Roofing.	To determine diaphragm capacities of the system using the following variables: 1. Joist size and spacing 2. Sub-purlin size and spacing 3. Standing seam roof thickness and anchorage.	The noted system has received increasing usage and attention as design moves away from flat roof buildings. Little if any knowledge of the systems diaphragm characteristics is available. Superfluous sub-strata of plywood or metal deck are often used to insure diaphragm action. Research is needed to verify how much shear per foot a given assemblage can be expected to carry, thereby eliminating unnecessary sub-state.	Jim C. Rose 1030 Hartford Highway Dothan, Al 36301 205-794-0792.

Subcommittee Comments

Work of this nature is more appropriately undertaken with industrial support.

Recommended Priority

Low

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S - 5	Prevention of the terrible loss in parking structures and garages.	We need all the help we can get in research, materials, specifications, design and maintenance to prevent the terrible loss and destruction in such structures from corrosion and spalling.		Carl C. Hansen, P.E. 8805 Cameron St., # 418 Silver Spring, MD 20910 301-588-1480.

Subcommittee Comments

Studies in this area relate to similar concerns for bridges. NSF and other agency support for infrastructures available. Research area overlaps into Materials Category.

Recommended Priority

Low

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV C - Building Structures

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S - 6	Assessment of Structure Condition by Dynamic Response.	A reliable model for assessing the soundness and expected service life of a structure, particularly bridges, from a dynamic response to impact. Experimental verification of analytical models is needed.	It is possible theoretically to assess the amount of damage to a structure by comparing its actual response to dynamic loading to the theoretical response based on the known structural member properties. Experimental verification and calibration research models are needed to make predicting the life-span of existing structures such as bridges practical. An extensive experimental program on a variety of bridge structures with simulated controlled damage is required.	Ariel Hanaor Rutgers University P.O. Box 909 Piscataway, N.J. 08855 201-932-4413.

Subcommittee Comments	Recommended Priority
Other agency sponsorship is more appropriate.	NA

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S - 7	Composite Columns with high - Strength Concrete.	With introduction of high-strength concretes ($f_c' >$ 10,000 psi) in high-rises, many design issues are arising.	In composite columns with high-strength concrete, (1) How is the shear transferred between steel & concrete? How are the column shear studs to be designed ? (2) What is the long-term durability, creep, toughness of the high-strength concrete? (3) What are the fire resistance characteristics? (4) In seismic zones, what is the ductility of such a system?	Nestor R. Iwankiw, P.E. American Institute of Steel Construction, Inc. 400 North Michigan Ave., Chicago Illinois 60611 312-670-2400.

Subcommittee Comments	Recommended Priority
1989's high priority project area on "Behavior and Strength of Composite Frames and Composite Building Frame Interaction" could be extended to include high strength concrete and behavior assessment under seismic conditions. Therefore continuation and extension of 1989 proposed project recommended as high priority.	High

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
5 - 8	Steel Space Frame Connection Behavior.	Virtually no information exists on the flexible connection behavior for steel space frames or two-dimensional frames subjected to three-dimensional loading.	Accurate analysis/design of steel space frames requires proper knowledge of the behavior. This knowledge base is not available for connections subjected to biaxial bending and/or torsion. A large database is available for plane frame connections.	George E. Blandford University of Kentucky Dept of Civil Eng. Lexington, KY 40506 606-257-1855.

Subcommittee Comments	Recommended Priority
Potential applications of this research work limited (1988 proposal on space frames was rated LOW also). CBT's tri-directional testing facility is eminently suitable for related experimental work and available for externally funded studies of this type.	Low

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
5 - 9	Lateral Stability of Long Slender Shearwalls.	How should slenderness effects in a direction perpendicular to the applied load on long narrow shearwalls be considered?	The trend is to incorporate shearwalls into partition walls, trying to limit the thickness of the shearwall to 7-5/8" (standard cmu partition wall thickness). This creates a very slender element at the compression end of the shearwalls. Design aids and technical research on shearwalls do not address this problem.	Sam Militello Greiner, Inc. 5801 Mariner Street Tampa, FL 33609 813-286-1711.

Subcommittee Comments	Recommended Priority
Insufficient specifics presented. Much analysis/design information available through past work in this area.	Low

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV C - Building Structures

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S - 10	National Design of Buildings with Partially Restrained Connections.	Nonlinear M-0 Curves can be developed (numerically or by experiment) To predict flexible joint response. No straight-forward approach short of finite element modeling is available to use this behavior in design of steel structures.	Study is required to develop simplified (relative to finite elements) methods for incorporating nonlinear joint behavior into analysis & design models.	R.J. Schmidt University of Wyoming Dept. of Civil Engineering Laramie, WY 82071 307-766-524.

Subcommittee Comments — **Recommended Priority**

This is substantially basic research and more appropriate to research efforts undertaken at academic institutions. — NA

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S - 11	Serviceability Design Criteria for Domestic Housing, Commercial and Industrial Buildings.	Acceptable performance under service loads needs to be defined-possibly through surveys of existing structures.	What are the static/dynamic characteristics of typical homes, apartments and office buildings? The information is necessary for true load and resistance factor design criteria. Compare static and dynamic performance of different types of construction materials i.e. wood frame, steel, and prestressed and reinforced concrete floors and roofs. Compare serviceability performance of U.S. construction to European and Japanese. This would facilitate design of acceptable/exportable building systems. Coop with FPL with regards to wood components.	Marcia Patton-Mallory Forest Products Lab., USDA One Gifford Pinchot Dr. Madison, WI 53705 608-264-5871.

Subcommittee Comments — **Recommended Priority**

Work is appropriate to other laboratories such as the Forest Products Laboratory. — *

Section IV C - Building Structures

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S - 12	Pultruded Fiber Reinforced Composites Construction.	Experimental and Analytical investigations are needed to examine the behavior of modern pultruded composite profiles under static and Dynamic Loadings. Design guidelines should be developed, for both building and bridge applications.	Modern pultruded fiber reinforced composite profiles (I-shapes, channels, angles, tubular sections) are candidates for use as structural members. Designers of such components lack dependable and reliable guides to follow. Research is required for 1) The strength-to weight and stiffness-to-weight ratios related to conventional metals. 2) Life expectancy and maintenance cost. 3) Insulation values at a wide range of frequencies and temperatures.	Abdul Hamid Zureick Georgia Institute of Technology School of Civil Engineering Atlanta, GA 30332 404-894-2204.

Subcommittee Comments	Recommended Priority
Project area is more appropriate to external or industry sponsorship as it relates to industrial and product development.	NA

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S - 13	Leakage of radon bearing soil gases into buildings through cracks in concrete slabs.		It is my view that a fundamental element of the solution to radon infiltration into buildings is the improvement of concrete slabs to be integrity barriers. Obviously this requires the development of systems with reduced cracking potential which can be successfully implemented in the field.	Richard W. Dixon, P.E. State of Florida Department of COmmunity Affairs 2740 Centerview Drive Tallahassee, FL 32399.

Subcommittee Comments	Recommended Priority
Improved crack control of concrete is more appropriately achieved through improved design practice. Research should find support from industry and organizations like PCA.	NA

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV C - Building Structures

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S -14	Wind Damage reduction through stricter interpretation of standards regarding uplift resistance of buildings.	My Opinion is that the great majority of wind casuality loss is simply and economically avoidable with proper attention to small details. And that is very substantial loss reduction is attainable.		Francis Biehl Biehl Engineering, Inc. N66 W12859 Ravine Drive Menomonee Falls, WI 53051 414-251-8251.

Subcommittee Comments	Recommended Priority
Improved or application of good design practices rather than research.	NA

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S - 15	Fire Division Wall.	If anchors are in the structure between adjoining buildings of extensive area - How to laterally stabilize property to prevent wall collapse during fire.	This will pull down the wall if collapse occurs. We need some guidance standards on this, I do not feel comfortable with my untested ideas on this!	Frances W. Biehl Biehl Engineering, Inc. N66 W12859 Ravin Drive Menomonee Falls, WI 53051 414-251-8251.

Subcommittee Comments	Recommended Priority
A design practice and detailing problem.	NA

Section IV C - Building Structures

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S - 16	1. Residential Wind Testing 2. Structural Testing Wall Assemblies. 3. Combined Shear-/Uplift tests of shear wall sections.	1. Establish wind load coefficients for detached residential buildings. 2. Determine load factors for composite action of wall assemblies. 3. Determine results and load factors for shear walls subjected to uplift.	1. Load coefficients for various locations on building structure. 2. Load factors for various wall assemblies. 3. Load factor for connectors in shear wall components subject to uplift.	Billy R. Manning Southern Building Code Cong. 900 Montclair Road Birmingham, AL 35213 205-591-1853.

Subcommittee Comments

Recommended Priority

Much information available. Quantum refinements require improved wind tunnel facilities - Refer to Project S-3.

NA

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S - 17	Criteria, Test Methods and Evaluation of Damping Characteristics of Base-Isolation System for Structures in Seismic Area.		There is an urgent need for improved engineering understanding in this field.	M.S. Chawla GSA, PBS 18th & F St., N.W., Washington, D.C. 20405 202-566-1700

Subcommittee Comments

Recommended Priority

It is suggested that CBT has special research expertise and facilities to undertake research in this field.

High

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV C - Building Structures

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
S - 18	Evaluation of Performance and Stiffness Contribution of Cladding/ Frame Behavior.		It was noted that this topic has been a high priority recommendation of previous NIBS panels.	Nestor R. Iwankiw, P.E. American Institute of Steel Construction, Inc. 400 North Michigan Ave. Chicago, Illinois 60611 312-670-2400.

Subcommittee Comments

Research data is considered important to improved analysis of cladding frame behavior and to improved design practice.

Recommended Priority

• Medium

SECTION D - FIRE SAFETY

The projects in this section are separated into two categories, Fire Science and Engineering, and Fire Measurement and Research. This is done to correspond with the organizational structure of the CFR which has divisions with the same titles.

1. FIRE SCIENCE AND ENGINEERING

Project Number	Project Title	Project Need	Data Required	Recommender/ Affiliation
F - E1	Ensuring Safety of Fire Fighters in Structural Fires.	Develop consistent techniques to evaluate the safety of fire fighters in various fire situations. Provide guidelines to the fire services community on handling specific applications.	Nonspecific	Dr. E.L. Schaffer US Forest Products Lab 1 Gifford Pinchot Dr. Madison, WI 53705 608-264-5688.

Subcommittee Comments	Recommended Priority
Project appears more related to personnel training than than to fire research. Could be done by organizations such as FEMA/USFA OR NFPA.	NA

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
F - E2	Performance Of Residential Fire Sprinklers Installed Under Open Wood Joist Construction.	Water supply requirements and design for residential sprinklers under open wood joist construction.	Design criteria is needed for codes and standards and for fire protection engineers.	G.R. "Clay" Claiborne Central Sprinkler Corp. 451 N. Cannon Ave. Lansdale, PA 19446 215-362-0700.

Subcommittee Comments	Recommended Priority
Research should be sponsored by sprinkler and/or wood industry. NIST does have the necessary facilities should industry financing be available.	Low

Section IV D - Fire Safety

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
F - E3	Smoke Purge - Positive or Negative Pressure.	Can smoke be removed safely and with less damage by blowing in fresh air and forcing out the smoke vs sucking in fresh air and blowing out the smoke.	The time smoke is in contact with the space objects has an effect on the magnitude of the damage. Which system is better; blowing or sucking, when dealing with smoke purge.	John C. Clark ASHRAE Michaud, Cooley, Erickson 825 Fourth Ave Minneapolis, MN 55415 612-339-4941.

Subcommittee Comments — **Recommended Priority**

Subcommittee Comments	Recommended Priority
This project should be considered as part of the general research done under F - E5.	High

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
F - E4	"Stamp Out Myth's About Sprinklers & Fire Suppression" Produce a Book or Video Tape that a Consulting Engineer could give to a Building Owner.	Building owner's have a fear of water (sprinkler systems); and do not understand the danger of secondary explosions from smoke. They say "water does more damage than fire"; "Water will damage my electrical equipment" or computer's, etc.	1. Statistics on property loss in sprinklered buildings vs non-sprinklered. 2. Statistics on real losses due to sprinkler malfunction. 3. An authority like the "NIBS" can make an authoritative statement from data, whereas one from a consulting engineer is opinion.	David Scheirman Determan-Scheirman, Inc. 2305 N. Meridian Okla, City, OK 73107 405-947-8626.

Subcommittee Comments	Recommended Priority
Project involves producing an educational packet based on existing statistical data available through NFPA and the sprinkler and insurance industries. It does not involve fire research.	NA

Section IV D - Fire Safety

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
F - E5	Mechanical Smoke Exhaust Effects on Fire Growth, Fire Spread and Fixed Fire Suppression Systems.	Many model and local codes require elaborate, automatic "smoke control" (i.e. exhaust) systems in buildings. There is no scientific body of data and analysis to show that this is a prudent fire strategy.	Mechanical ventilation effects on heat and mass transfer from a fire plume. Mechanical ventilation effects on fire oxygenation. ASHRAE is very concerned about the potential of automatic systems to exacerbate an already bad situation. ASHRAE & NRC (Canada) are currently discussing a cooperative research program to address some of these issues, but the scope and scale of such a program may exceed current resources.	Michael E. Dillon ASHRAE 38 N. Marengo Ave. Pasadena, CA 91101 818-449-8948.

Subcommittee Comments	Recommended Priority
A general project on smoke control that would involve full scale testing as well as modelling.	High

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
F - E6	Investigation of Fire Sprinklers in Non-Sprinklered Existing Buildings by use of Stand Pipe Risers or Domestic Water Systems.	Are fire sprinklers connected to stand pipes or domestic water systems effective for quenching fires in buildings, regardless of height? How safe?	An economical method of adding fire sprinklers in existing buildings. There are some economical ways to provide sprinklers, however, they are not in accordance with NFPA 13. Exposed sprinkler pipe could be installed down each corridor to provide sprinklers for the exit corridors. Have municipalities consider other incentives (other than possibly insurance) such as: (1) No permit cost (2) Design help in installing modified sprinklers. (3) Some type of tax break incentive. (4) A fire watch from the Fire Department while existing fire lines are tapped.	James R. Graves Graco Mechanical, Inc. 5810 Schumacher Houston, Texas 77057 713-878-7000

Subcommittee Comments	Recommended Priority
Project is not directly applicable to fire research as stated, but demonstrates the need to investigate water flow requirements for standard sprinkler system.	Medium

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV D - Fire Safety

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
F - E7	Effectiveness of Compartmentation in reducing Fire Hazards.	Current guidelines for evaluating the effectiveness of various types of barriers in reducing fire hazards are based primarily on research performed in the 1920's. New technology has not been used to substantially update the standards pertaining to evaluation of barriers. Current arbitrary rating systems do not directly address how well a barrier will reduce a type of fire hazard.	A) Tests to obtain reliable data for fully developed fires to be used with models currently under development at NIST. B) Full-scale fire tests to validate the accuracy of NIST computer models under for later stages (half hour or more) of fully-developed fires. C) Development of analytical (computer) models to evaluate hazards associated with the performance of barriers and other structural elements in a fire.	James P. Hurst Portland Cement Association 5420 Old Orchard Rd. Skokie, IL 60077 312-966-6200 x 351.

Subcommittee Comments	Recommended Priority
The study of compartmentation effectiveness requires full-scale test facilities that NIST does not have operational at this time. It will be necessary in the future to extend fire modeling to fully-developed fires and consideration of structural fire resistance. Other aspects of fire modeling need to be considered first, however.	Medium

Section IV B - Fire Safety

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
F - E8	Toxic Smoke Hazard of Materials in HVAC Plenums.	Utility wiring is usually located in plenums formed by suspended ceiling material of a room and the bottom surface of the floor above. The plenum space also contains ductwork, usually insulated, and serves as the HVAC system. Some wire insulations are known to produce, smoke when burned.	Although the hazard created by burning the individual materials may be known, the hazard presented when spaces served by such plenums become involved in fire or in smoke control are not known. Full Scale tests may be required. (High Priority last year)	Herbert T. Gilkey, PE Engineering Consultant 2808 E. Meredith Drive Vienna, VA 22181-4039 703-938-0514

Subcommittee Comments	Recommended Priority
This project forms a part of a high priority research effort to identify cumulative toxic hazard of all material in a building.	Medium

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV B - Fire Safety

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
F - E9	Effect of Supply and Exhaust Air Movement on Smoke Detectors.	Residential and commercial building smoke detectors are frequently located near HVAC supply outlets/return intakes, or in return air plenums. Excessive air motion across the sensing elements of a smoke detector may dilute the smoke concentration or reduce detector sensitivity and responsiveness, causing a malfunction.	Information on the effect of air movement on smoke detector sensitivity and responsibility is needed.	Herbert Gilkey, PE Engineering Consultant 2808 E Meredith Drive Vienna, VA 22181-4039 703-938-0514

Subcommittee Comments	Recommended Priority
The Fire Detection Institute and NFPA Research Foundation are attempting to agree on a research program to study this topic.	Low

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
F - E10	Test Method of Using Polybutylene Pipe for Sprinkler Systems.	No fire trip/failure of sprinkler systems. Need piping system that can tolerate freezing.	Codes now require piping that can not tolerate freezing. Note: Any technology that will allow a wet fire sprinkler system to tolerate freezing is required.	Gene Smith Sunbelt 1430 W. Peachtree St Atlanta, GA 30309 404-875-8173

Subcommittee Comments	Recommended Priority
Code via NFPA sprinkler standards already allow the use of listed plastic sprinkler piping.	NA

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV D - Fire Safety

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
F - E11	Simplified Approach to Reduce Cost of providing adequate Fire Protection for certain Steel members.	The problem is regulatory "over-kill". Major objective of the research would be to reduce such by application of logical evaluations of how much protection is sufficient to provide "adequate" fire protection. Examples: steel columns in the open vs. those in a fire rated wall assembly, roof members in the open vs. those above a fire rated ceiling.	There are various protection assemblies for steel columns and beams exposed to fire in the open (included in the table 43A of the Uniform Building Code). Table 43B of the UBC gives fire-resistive ratings for various walls and partitions, and table 43C rates ceiling assemblies. These are, in general, based on the underwriter laboratory's "Fire Resistance Directory" and the Gypsum Association's "Fire Assistance Design Manual". The "Technology Gap" occurs when one hour fire resistive construction is needed. A steel column is frequently used in a wood frame wall; since there is no specific mention in the reference documents about such use, it has been held that the column must be individually wrapped.	J.B. Barrish Barrish, Pelham & Partners, Structural 2715 V. Street, Ste. C Sacramento, CA 95816 916-453-1000

Subcommittee Comments

This is not a fire research project, unless current methods of testing fire resistance of building components are to be revised.

Recommended Priority

NA

Section IV D - Fire Safety

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
F - E12	HPM exhaust duct, fire suppression.	There is significant need to control fire spread with HPM ducts. There has been very little large scale testing performed. Risks are high to worker life and safety and contamination of environment.	Are duct sprinklers effective? If so, what type head, spacing, hydraulic characteristics are required? How does air velocity and duct configuration affect the suppression system?	

Subcommittee Comments	Recommended Priority
Insufficient information to determine how fire is spread through HPM exhaust ducts. Initial appraisal is that this is a limited industry-specific research project.	NA

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
F - E13	Effectiveness of engineered smoke control systems in large buildings.	The effectiveness of smoke control methods under actual conditions is not known. Information is lacking on what does and what does not control.	1. Analytical approaches 2. Experimental approaches (full scale systems) testing 3. testing under simulated conditions using reduced scale building models. This technology is available in the Soviet Union.	Jon Caloger Gamze-Korobkin-Caloger, Inc. 205 West Wacker Dr. Suite 2100 Chicago, ILL 60606 312-641-5888.

Subcommittee Comments	Recommended Priority
This project is worth while and should be considered as part of the research done under F-E5.	High

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Section IV D - Fire Safety

2. FIRE MEASUREMENT AND RESEARCH

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
F - R1	Fire Model for Charring Wall Linings in Compartments	Develop appropriate algorithms that describe the fire process on charring materials, such as wood. Develop data base on fire properties of materials in corner configurations.	Nonspecific	Dr. E.L. Schaffer US Forest Products Lab 1 Gifford Pinchot Dr. Madison, WI 53705 [redacted].

Subcommittee Comments	Recommended Priority
This research is presently in progress at NIST. Contribution of wall coverings to fire growth is critical to proposed fire models.	High

Project Number	Project Title	Research Need	Data Required	Recommender/ Affiliation
F - R2	Effects of floor plan on fire performances of indoor spaces.	Open floor plans are common in the office and in homes. What are their specific effects on the progress of fires?	Correlate floor plans and interior laynuts on the spread of fires and the ability of sprinkler systems and/or non-combustible construction materials to reduce fire damages. Can fire protection suppression systems be more effective with certain floor plans?	Bion D. Howard NAHB 400 Prince Georges Blvd. Upper Marlboro, MD 20772 301-249-4000.

Subcommittee Comments	Recommended Priority
This project might have future benefit as a refinement to current research which is still considering the gross problems of fire behavior.	NA

NIBS RECOMMENDATIONS FOR NIST RESEARCH

Appendix 1.

The members of the organizations listed below who contributed suggested research topics and assisted with this report represent the breadth of the construction industry. They are named in chapter IV with their individual projects and their contributions have allowed NIBS to present valid and specific research recommendations which reflect stated industry needs.

American Consulting Engineers Council
American Institute of Architects
American Society of Civil Engineers
American Society of Heating, Refrigerating and Air-Conditioning Engineers
American Society of Testing and Materials
Building Officials and Code Administrators International
Building Thermal Envelope Coordinating Council
Building Owners and Managers Association
NIBS Membership (Includes Building Seismic Safety Council and Wood Protection Council)

Their efforts and suggestions also exhibit the willingness of the industry to continue to contribute to the cooperation between public and private research organizations involved with the building sciences. This report underlines the NIBS' position of continued support for beneficial building sciences research by the NIST.

NIBS also thanks the volunteer members of the project committee and other building community professionals, especially the subcommittee chairmen, whose names are listed below with their subcommittees, for their time and expertise as contributors and reviewers for this document. The results of their contributions demonstrate the value of the consensus forum for assisting in the determination of future technical research directions.

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NIBS RECOMMENDATIONS FOR NIST RESEARCH

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NIBS RECOMMENDATIONS FOR NIST RESEARCH

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An Evaluative Report on the Center for Building Technology

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This report, submitted for the Panel by the Chairman, Kenneth F. Reinschmidt, is an annual assessment of the activities of the Center for Building Technology, based on a meeting of the Panel on December 16-17, 1987.

Functions of the Center

The Center for Building Technology (CBT), a part of the National Engineering Laboratory (NEL), increases the usefulness, safety, and economy of buildings through the advancement of building technology and its application to the improvement of building practices.

The Center is the national building research laboratory. It works cooperatively with other organizations, private and public, to improve building practices. It conducts laboratory, field, and analytical research. It develops technologies to predict, measure, and test the performance of building materials, components, systems, and practices. This knowledge is required for responsible and cost-effective decisions in the building process and cannot be obtained through proprietary research and development. The Center provides technologies needed by the building community to achieve the benefits of advanced computation and automation. The Center does not promulgate building standards or regulations but its technologies are widely used in the building industry and adopted by governmental and private organizations that have standards and codes responsibilities.

During fiscal year 1988, the Center had a staff of about 120 federal employees plus 40 research associates and guest workers, and a total operating budget of approximately $11 million.

Summary of Findings and Recommendations

The Panel strongly recommends that the Center for Building Technology be maintained as an integral part of NEL and NBS. The Center is a unique institution and the only national laboratory in the United States dedicated to research in building technology. If it did not exist, CBT would have to be created. Its loss would do great damage to the

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future technological leadership of the U.S. building industry.

The Panel finds that research carried out in the CBT is relevant to its mission and that of NBS, and clearly is of great importance to the building community. This valuable work would not be pursued were it not for the CBT. The Panel also finds that the work is executed in a highly competent fashion by a well-qualified staff that includes some extraordinarily gifted researchers who pursue their work with great enthusiasm.

The equipment and facilities available to the CBT are excellent and, in general, adequate for current research. Financial support to keep this equipment, some of which is unique to the NBS, adequately maintained and in productive use is essential.

The personnel of the CBT are highly motivated, and the Panel is pleased to note that morale is remarkably high, considering the financial uncertainties of the CBT. Nevertheless, the years of uncertainty about funding, the questions concerning CBT's existence, and the yearly reductions in budget have had adverse effects on staffing. The staffing problem is particularly critical at the senior level. Several outstanding senior researchers have departed to universities and other government agencies. The Center is still able to recruit excellent young researchers, but its ability to retain them and to hire senior personnel to replace losses will be seriously in question if the funding issues remain unresolved.

A significant increase in directly appropriated funds is urgently needed, if only to offset the effects of inflation in the past 8 years. Need for new funding is so great that additional outside-agency funds are required as well. Therefore, the Panel recommends that the CBT increase efforts to make its work more visible to the construction industry, the Congress, and the administration.

The Panel is aware of the Hollings Bill (S. 907), which would rename the NBS the National Institute of Standards and Technology and mandate new activities in research and technology transfer. Although the future of the Hollings Bill remains uncertain, the need for the CBT to expand its role in technology transfer is clear. This theme runs throughout this report.

Technology transfer—from overseas to the United States; from national laboratories and universities to federal, state, and local agencies; and from government to the private construction industry—could become a major thrust of the CBT. Although more directly appropriated funding is needed to support technology transfer fully, technology transfer could become a key factor in increasing funding from other agencies and even from private industry for the work of the CBT.

The Center for Building Technology has unique personnel and equipment that are not duplicated anywhere in the public or the private sector. As one Panel member stated, "The CBT is the only place in the United States where construction materials research is taken seriously." In addition to unique strengths in specific areas, such as metrology, large-scale testing, structural evaluation, thermal testing, environmental testing, etc., the CBT is unique in the United States in having all these capabilities under one roof. Synthesis of these capabilities is perhaps even more important than the strengths in each speciality. The Panel recommends that the CBT take greater steps to integrate the work of its various divisions and groups to achieve a greater degree of focus of its activities.

Research in construction processes and technology is vital to the international competitiveness of the U.S. construction industry. Technological leadership not only affects the international competitiveness of U.S. construction firms, it also affects the domestic building industry.

The CBT has undertaken to address this rapidly emerging technology with its own resources, through its initiative in computer-integrated construction. In addition to the CBT, the National Science Foundation and the Building Research Board of the National Research Council have recognized computer-integrated construction as an important emerging technology. Many universities are undertaking research in this area, but their individual resources are insufficient to achieve the necessary critical mass. Computer-integrated construction research requires the coordination of technologies such as computer-aided design, robotics, large-scale metrology, artificial intelligence, computer science, database design, data communications, quality control, and building science.

The Panel encourages the CBT, in collaboration with the NBS Automated Manufacturing Research Facility, to plan for a national resource center at NBS for research in computer-integrated construction. Also the CBT should develop new research programs and proposals organized around this unifying theme.

In the interest of brevity, only a few major recommendations have been made here; others are suggested in the remainder of this report. Regardless of which suggestions are taken, the Panel believes that the CBT must focus and coordinate its research program and seek additional funding for initiatives clearly in the national interest.

Structures Division

The Structures Division, as its primary objective, develops the technical base for predicting the behavior of various structural systems and materials used in buildings and bridges, so as to enhance the performance of these structures, to increase their service lives, and to improve their reliability.

The Structures Division continues to have the responsibility for the execution of two NBS roles assigned by Congress. The NBS Authorization Act for Fiscal Year 1986 directs NBS to investigate, after consultation with local officials, the physical causes of major building and construction failures; to report their causes promptly and publicly, and thus to help preclude recurrences of these failures. The Authorization Act also calls for NBS to provide for the creation and maintenance of a database on structural failures. In the Earthquake Hazards Reduction Program, NBS is assigned the responsibility for research and technical support for the development of seismic design and construction provisions.

The Structures Division is actively pursuing significant research work in the following areas: earthquake engineering, building lateral stiffness, seismic behavior of precast concrete systems and connections, behavior of reinforced concrete walls subject to in-plane shear loading, nondestructive impact-echo test methods, and punching shear capacity of curved arch/plate structures.

The morale of individual investigators and of the Structures Division as a whole is high in spite of the continuing budgetary pressures. The level of the individual research efforts and the qualifications of the research staff are excellent. The efforts of the Structures Division on the investigation of the collapse of the L'Ambiance Plaza in Bridgeport, Connecticut, for the Occupational Safety and Health Administration, and the evaluation of the U.S. Embassy building in Moscow for the State Department were significant accomplishments in 1987 and gained major recognition by the public and the Congress.

Although the total professional staff of the Structures Division increased from 14 to 17 in the past year, the attrition of key senior staff members has led to a reduction of the research capability in several key areas, especially earthquake engineering. The Panel recommends that the Structures Division increase its efforts to recruit a senior researcher in earthquake engineering to enable it to continue to exert the necessary leadership in this critical area and to fulfill its mandated role in the Earthquake Hazards Reduction Program.

The laboratory testing equipment of the Structures Division is of special importance. The high-bay, 12-million-pound testing machine and the three-dimensional computer-controlled load facility are unique national resources. There is a problem in obtaining funding for the maintenance of this equipment. The Panel recommends that the CBT develop a budget for preventive maintenance to assure that this equipment is maintained in topnotch condition, so that the Structures Division can continue to perform essential specialized testing.

Although the Structures Division achieved national recognition for the structural investigations of the L'Ambiance Plaza and of the U.S. Embassy in Moscow, these events highlighted the understaffing in the Division. With the attrition in senior positions and these two unexpected assignments, the staff of the Structures Division has been spread thin. As a result, other major goals set in 1987, such as the startup of new programs and the recruitment of a head for the earthquake engineering section, could not be addressed, and progress in several key research areas has lagged. Currently, the CBT is investigating the collapse of the Ashland oil tank in Pittsburgh, Pennsylvania. These unpredictable events emphasize the need to bring the staff of the Division up to strength in order to meet ongoing responsibilities and special assignments simultaneously.

The Panel recommends that the Structures Division continue and extend its research in the following areas.

Flaw detection (impact-echo) in concrete slabs and structures. Research to date has achieved significant success and is very important. This technology should be extended to detect voids beneath pavements. In addition, radar sensing methods should be extended to develop scour detection for major bridge piers. Investigation of the collapse of the Schoharie Bridge on the New York State Thruway demonstrates the urgent need to predict and identify scour at bridge piers in riverbeds.

Punching shear strength of thick concrete structures. Structures Division research sponsored by offshore drilling firms has resulted in significant new findings concerning the punching shear behavior of flat surfaces compared to curved surfaces.

Testing of hollow cylindrical sections and columns with spiral reinforcing of various types and strengths. The bridge column test program has been substantially completed. All tests were performed on solid concrete sections.

Leading to a code for seismic behavior of precast concrete structures. Testing of reinforced masonry walls subjected to seismic forces should continue. (The Structures Division should recruit a new leader for the Earthquake

Engineering Group and take a leadership role in the earthquake engineering research community.)

The Panel also recommends that the Structures Division conduct national workshops for principal investigators on individual research grants and to coordinate the parallel structural research efforts sponsored by various government agencies. These workshops would establish CBT as the national focal point for technical information in structural engineering.

The CBT should conduct a workshop for technology transfer in structural engineering to achieve the purposes of the Hollings Bill.

The Structures Division should assess the state of the art of measurement techniques for determining building motion and convene a national workshop to disseminate instrumentation technology within the structural engineering community and to identify the needs for instrumentation of the construction of high-rise buildings. In addition, the Structures Division should set up a program to monitor the behavior of high-rise structures in several major cities, in order to establish the correlation between the design predictions and the actual performance of these buildings.

In summary, the leadership of the Structures Division and the technical competence of its professional staff are excellent. The ongoing research programs and the proposed new areas of research are relevant, significant, and beneficial to the nation and the construction industry. Replenishment of personnel is the most important requirement at this time. Recruitment of a new head for earthquake engineering should have top priority. Financial support for the maintenance and use of the specialized testing equipment is also very important. In order to support this unique resource, increased marketing of the testing facilities to the construction industry may be necessary.

Building Environment Division

Programs of the Building Environment Division are critical for the worldwide competitiveness of the U.S. building systems industry, for economic energy conservation methods, and for an improved human environment. In 1987, the major initiatives of the Division were directed toward finding replacements for the chlorofluorocarbon refrigerants used in air conditioners, which are degrading the ozone layer, and toward improved measurement and monitoring techniques for both overall building performance and improved indoor air quality. The Division reduces the cost of designing and operating buildings and increases the international competitiveness of the U.S. building industry by providing modeling, measurement, and test methods needed to use advanced computation and automation effectively in construction, improve the quality of the indoor environment, and improve the performance of building equipment. It conducts laboratory, field, and analytical research on building mechanical, control, security, and lighting systems; develops data, measurement methods, and modeling techniques for the performance of the building envelope, its insulation systems, building air leakage, the release, movement and absorption of indoor air pollutants, and natural light; and develops software performance criteria, interface standards, and test methods needed for the nation's building industry to make effective use of modern computer-aided design hardware and software, and database management systems.

The quality of these efforts is excellent, and the Division's activities encompass many areas not being addressed by either the academic community or the building industry. In 1987 the continuing funding problems of the Division resulted in the termination of 14 experienced employees. However, an aggressive approach to obtaining additional external funds and participation in two major efforts critical to the health and safety of the nation have resulted in a very creative work environment and the restoration of employee morale. The Division receives nearly 75 percent of its funding from other-government agencies.

The Panel believes that the Division should develop a 5-year strategic plan, the main purposes of which would be to assess the strengths and weaknesses of the Division and to develop strategies for funding critical research activities.

The management of the Building Environment Division is commended for its support of travel to technical conferences, presentation of technical papers, and participation in committee work. Through these means, the Division is making substantial contributions to the work of organizations such as the American Society of Heating, Refrigeration, and Air Conditioning (ASHRAE).

The Mechanical Systems and Controls Group has made a remarkable turnaround in morale in the past year. The Group has successfully marketed its capabilities, matched with the needs of supporting agencies. Specific items of work by the Group include a 2-year pilot program, funded by the General Services Administration (GSA), to develop commissioning procedures for heating, ventilating, and air-conditioning (HVAC) control systems in large federal office buildings. These procedures will be included in construction specifications for GSA work.

Also under development is the design of computer software to emulate an HVAC system and its associated building spaces. This emulator will be used to simulate the operation of a proposed building control system. The objective of this effort is the development of a prequalification package to determine the most efficient control system for a particular building.

The Mechanical Systems and Controls Group is responsible for the development of a combined heating/cooling and domestic water supply evaluation protocol for the Department of Energy (DOE), to determine the efficiency of combined space heating and domestic hot water generation systems. At the present time, each component of a system (boiler, furnace, and hot water heater) is tested separately. There has been a recent trend toward combined systems, but there is as yet no method for evaluating their combined efficiency; this program will remedy the deficiency.

The Mechanical Systems and Controls Group enjoys an outstanding reputation as a leader in HVAC. Its programs focus on reducing the energy cost of buildings through the development of integrated and optimized building systems and the creation of design tools, diagnostic procedures, and performance evaluation techniques necessary to quantify such systems. A common aspect of these projects involves technology transfer to the private sector. This is accomplished through technical publications, participation in technical committees, and organization of workshops and symposia. Members of the Mechanical Systems and Controls Group are active in the International Council for Building Research (CIB), ASHRAE, and the American Society for Testing and Materials (ASTM). Major symposia organized by the Group include a workshop on intelligent buildings, a workshop on recent advances in the control and operation of building HVAC systems, and a symposium on the performance of HVAC systems and controls in buildings.

The Thermal Machinery Group is conducting promising work on chlorofluorocarbon refrigerants, standards for variable speed drives in heat pumps, computer models for the evaluation of heat exchanger efficiency, and computer models for evaluation of expansion devices.

Japanese technology for variable speed drives in residential heat pumps is well ahead of U.S. technology. These variable speed drives provide a potential 25 to 30 percent saving in operating costs. However, the simple thermostatic control systems used in most U.S. residences are not sophisticated enough to allow the system to run at maximum efficiency in order to attain the theoretical cost savings.

A breadboard heat-pump test facility at the CBT allows the study of a wide variety of refrigeration cycles and refrigerant combinations. This facility has demonstrated that the use of refrigerant mixtures can result in a 32 percent increase in heat-pump efficiency. *This is a noteworthy accomplishment.* A recently completed 5-year research program explains the degradation of the boiling heat transfer coefficient for rapid flow of nonazeotropic refrigerant mixtures, compared with that of a single-component refrigerant. The key research is aimed at the development of refrigerant mixtures that can be used without significant modifications to existing equipment, but will have minimal impact on the ozone layer of the upper atmosphere.

Due to losses of the ozone layer, it is likely that the production of the two most common refrigerants used in residential construction, R-11 and R-12, will be frozen at 1986 production levels and decreased by approximately 50 percent by the end of the century. It is necessary to find alternative refrigerants for applications such as refrigerator/freezers, automobile air conditioners, and foaming agents for insulation.

The Thermal Machinery Group, with extensive sponsorship, is developing the thermodynamic and transport property data for various mixtures of refrigerants, and is simulating the design of heat pumps using those mixtures. Two candidate mixtures, identified as 134A and 123, are believed to be usable as refrigerants in new installations. The properties of these fluids, it is hoped, will closely match the characteristics of R-11 and R-12, so that major machinery modification will not be required. A patent application has been made for an azeotropic mixture of R-216 and R-11 that will increase the capacity of a chiller, without exceeding the tip speed limits of the compressor blades. Commercial development of this concept for 50-Hz compressors is being considered.

The Heat Transfer Group's major research objectives are to develop a greater understanding of the transfer of heat, air, and moisture through building envelope components, and to assist standards-setting organizations in the development of test methods. In the past year, the Heat Transfer Group has been involved in four research areas: development of a dynamic test procedure for wall systems; selection of a low conductivity standard reference material (SRM); evaluation of the impact of the ban on chlorofluorocarbon agents used in the manufacture of foam insulation products; and refinement of a moisture transfer model.

Development of a dynamic test method for a calibrated hot box is extremely important to industry because some walls are so complex that the dynamic response cannot be predicted. The pioneer work of the Heat Transfer Group has resulted in an ASTM test standard in which all walls can be thermally characterized.

The Heat Transfer Group's guarded hot plate and calibrated hot box are world-class testing facilities. Sponsorship by outside agencies of research to increase the use of these facilities to advance the basic understanding of heat and moisture transfer should be aggressively pursued.

As new test methods are devised, SRMs with low thermal conductivity must also be developed. Recently, the CBT guarded hot plate facility has been modified for this investigation. Test materials have been obtained and the Heat Transfer Group is measuring thermal conductivity as a function of mean specimen temperature and pressure. When this work is complete, the material will be distributed through the NBS Office of Standard Reference Materials.

The accumulation of moisture within building materials has a serious impact on building performance. There is a lack of fundamental information on which to build mathematical models that predict the effects of moisture transfer on material performance. The Heat Transfer Group has developed a complex model for this purpose and during the next year will measure the input coefficients for moisture and temperature gradients in various materials. The moisture content of small-scale wall sections will be measured and compared with the values predicted by the model, at various elapsed times. This work should lead to a fundamental understanding of the movement of moisture through various materials and to improved commercial building materials that will reduce the effects of moisture in buildings.

The research activity of the Indoor Air Quality and Ventilation Group continues to build on its considerable strength in techniques to advance the understanding of the technical determinants of indoor air quality. Important progress has been made in the development and articulation of a mathematical simulation model of indoor air quality in the residential environment. In common with other such models, it functions as the coherent repository of the experience the Group has developed in making measurements of infiltration and active air intake in office buildings. The CBT model is unique in that it incorporates the quantitative effects of all of the factors determining indoor air quality at a medium level of spatial resolution and at a useful level of detail.

The measurement of total building air exchange by simultaneous evaluation of building envelope infiltration and ventilation system air intake provides important insights into the overall performance of building envelopes interacting with ventilation systems. The magnitude of the infiltration term has consequences for energy conservation strategies as well as for the establishment and implementation of ventilation standards.

The Indoor Air Quality and Ventilation Group is an important participant in ongoing multidisciplinary studies of large buildings with a sustained history of unsatisfactory indoor air quality. This activity is of great importance in resolving the multiple causes of such problems. The Group's participation ensures that the physics and engineering aspects of the indoor air quality problem are competently evaluated and interpreted, a requirement if preventive engineering prescriptions are to result from these investigations.

The Indoor Air Quality and Ventilation Group continues with a well-conceived attack on a very important and heretofore poorly understood characteristic of the building environment. Its contributions have been and should continue to be of great importance both in the correction of existing defects and in the development of standards and practices to prevent such defects from occurring in existing and new buildings.

The Lighting Group has continued to make good progress on several fronts despite being severely handicapped by the complete absence of base funding and the consequent necessity to obtain outside funding for every project undertaken in 1987. This handicap will continue in 1988 even though a small amount of base funding has been allocated to the Group.

The test room for studying the interaction between lighting and HVAC systems has been completed and data collection has begun. Already some interesting results have been obtained. The principal investigator is competent, hard working, and capable of putting this versatile facility to excellent use in the future, not only for the lighting and HVAC work, but also for evaluating the photometric properties of different systems.

The Lighting Group has done valuable work on the postoccupancy evaluation of lighting facilities. This work has had several sponsors, including the GSA, the U.S. Army, and the Lighting Research Institute, and has contributed to the understanding of the physical measurements needed to define the lighting environment.

Some other projects that the Lighting Group has undertaken in the past year have been of a job-shop nature. All have been done well, although in some cases the limited funding has prevented the Group from doing enough work to significantly augment its range of proficiency and its depth of expertise. Consequently, these projects have not all contributed as much as they might have to the long-term development of the Group.

The Lighting Group has made remarkable and successful efforts to locate outside funding. This success is particularly noteworthy in view of the necessity to tailor the funding proposals to the specialized talents of the staff. These efforts should be expanded to build on the existing strengths of the Group in the areas of lighting-HVAC interaction, postoccupancy evaluation, safety and signaling colors, and the application of physical measurements and principles to the analysis of complex visual fields. Funding should be sought to support additional staff to work, under the supervision of current members of the Group, on limited-term contracts for specific projects related to these main themes. This funding would enable the Group to focus on its existing strengths and thereby give more long-term direction to its work.

One of the main initiatives of the CBT is the measurement and improvement of indoor environmental quality. Although attention has focused mainly on air quality, lighting should not be neglected. Lighting is a major element of environmental quality, but one that is difficult to quantify in a meaningful way. Measurement of lighting quality requires not only accurate physical measurements, difficult in themselves, but also techniques for interpreting the measurements in a way that relates to the requirements (e.g., health, safety, and productivity) of the building occupants. Within the NBS environment, where the development of improved measurement technology is paramount, CBT is in an ideal position to play a major role in enhancing knowledge of how to measure lighting quality by bridging the gap between physical measurements and measurement in a more general sense, in which meaningful numbers are produced.

The Lighting Group should not be allowed to wither away. Rather, its strong points should be used as a base for a vigorous effort to increase knowledge and understanding of the role of lighting in the built environment.

Building Materials Division

The basic goal of the Building Materials Division is to advance the science and technology of construction materials in the United States through transfer of available knowledge to the construction industry. Specifically, the goal is to improve the international competitiveness of the building materials industry by conducting advanced research and development, in close cooperation with academic and industrial research, in the development of methodologies of measurement and service life prediction; improved criteria and standards for evaluation, selection, use, and maintenance of building materials; and improved or new tools to aid the making of sound technical and business decisions concerning construction materials.

In the Panel's view, the extension of service life of buildings, proper repair, and, if needed, total replacement of construction materials in buildings are crucial for maintaining the high quality of the rapidly deteriorating national infrastructure. To quote from a recently released report by the National Research Council:

> "The construction and repair of buildings and other structures constitute a substantial portion of the gross national product. Many of the structures, as well as a considerable segment of the public and private infrastructure, including highways, airport and maritime facilities, and municipal sewage systems, are made of concrete. Contrary to the beliefs of some, concrete is not indestructible, and appropriate maintenance of these structures must be provided for." (*Concrete Durability: A Multibillion-Dollar Opportunity,* National Materials Advisory Board, NMAB-437, National Research Council. 1987.)

The same statement could be made about other construction materials, including asphalt-based products such as roofing, organic coatings, and metallic materials.

In 1987 the Building Materials Division was active and successful in several areas crucial to understanding the field performance of building materials; this has been done through dissemination of scientific knowledge (in publications and presentations) as well as by assuming leadership roles in important national and international standards and technical organizations. At the same time, the Division has faced serious challenges in staffing and funding. Considering these challenges, the Panel is much encouraged to see that meaningful progress has been made in all three areas of current activity: organic building materials, inorganic building materials, and the Construction Materials Reference Laboratories (CMRLs).

The Organic Building Materials Group has concentrated its activities primarily on two important areas: roofing and protective coatings for construction steel. As is the case with inorganic building materials (e.g., cement-based concrete or gypsum products), these two areas need government attention, for the solution of the problems is beyond the present capabilities of individual construction materials producers.

The roofing-related work has focused on providing the technical basis for the prediction of the performance and service life of low-slope, single-ply roofing systems, and on modified bitumen roofing materials. The Panel is impressed by the quality of this work and is encouraged to see well-developed plans for the future. The approach taken for service-life prediction, through continuous development of test methodologies, is excellent and should be fully supported in the future.

The objective of the program on coatings is to apply general service life prediction methodology to the evaluation of protective coatings for steel. Corrosion of steel in constructed facilities is one of the primary reasons for the deterioration of the infrastructure. Even so, the application of steel coatings is estimated to cost the United States more than $10 billion per year, and even small improvements in the performance-cost relationship could lead to substantial savings and the extension of the service life of constructed facilities. Meaningful progress has been made in the better understanding of the mechanisms controlling the degradation of the steel-coating interface, as well as in the development of testing methodologies. An IR-100 award was given in 1987 to a team from the Building Materials Division for its development of a technique for rapid determination of surface profiles of sand-blasted metal and other materials.

The Inorganic Building Materials Group has concentrated its 1987 activities on the development of a conceptual and mathematical model of concrete microstructure and concrete behavior, thus forming the basis for the prediction and improvement of performance (primarily strength) and durability (life extension). This work required state-of-the-art research on the modeling of hydration reactions, microstructure development, and mechanisms of concrete deterioration. Substantial progress has been made in all three areas and the Panel recommends that this work continue.

Such continuation will require filling the available staff vacancies with first class professionals, and establishing meaningful cooperation with industrial research and management groups. In view of the present low level of concrete materials research in the United States (National Materials Advisory Board Report 361, National Research Council, Washington, D.C., 1980; Transportation Research Board Special Report 202, National Research Council, Washington, D.C., 1984; and National Materials Advisory Board Report 437, National Research Council, Washington, D.C., 1987), replacement of the recently departed staff members of the Inorganic Building Materials Group is essential to maintaining a critical mass of U.S. researchers in this important field.

Excellent work continues to be generated by the CMRLs and the American Association of State Highway Transportation Officials (AASHTO) Materials Reference Laboratory (AMRL), which have the goals of providing measures of quality for laboratories nationwide that test cement, aggregates, soil, bituminous materials, and other engineering materials; and improving standard test methods for those materials. This program for evaluation of the quality of laboratory testing is carried out in close cooperation with ASTM and AASHTO, and could serve as an example of significant interaction between government and private enterprise. The CMRL programs are continually being upgraded to reflect the introduction of new materials, changes in standards, and the introduction of advanced instrumentation and computing facilities. This highly visible CBT activity deserves compliments and encouragement for the future.

As mentioned above, the Building Materials Division faces many challenges, but the overall quality of the work and its importance to the nation remain high, and the Division deserves full support. Among the challenges, the following are of highest priority: personnel, stable funding, equipment upgrade, cooperation with the construction industry, and visibility.

The staff of the Building Materials Division is highly motivated and generally of the highest quality. Recent resignations have somewhat eroded the Division's capabilities, especially in the area of inorganic materials. The Panel recommends strengthening the Building Materials Division staff with professionals capable of performing first-class research and development and, at the same time, capable of establishing close relationships with the U.S. construction industry. A balance between entrepreneurial and highly creative professionals is needed.

Stable funding is one of the preconditions for any successful long-term research and technology transfer program. The present internal funding is inadequate and is deteriorating; at a minimum, internal funding should grow to keep up with inflation. Under the present circumstances, the Panel recommends that the CBT attempt to increase its research and development funding from other government agencies. For example, the CBT might coordinate important national activities in the construction field, specifically the use of construction materials and the preservation of constructed facilities. Novel funding mechanisms should be explored; for example, the insurance industry might be approached to fund parts of the earthquake-related research and development.

Although the Building Materials Division is very well equipped, the Panel proposes that the equipment be upgraded further. State-of-the-art equipment is critical for the main missions of the Division: measurement and prediction. Advanced computing and research instrumentation is needed for surface and interface characterization, for both organic and inorganic materials. To maximize the effectiveness of this equipment, close cooperation with other divisions of the NBS is essential.

Cooperation with industry could be improved by better dissemination of the CBT capabilities, especially in areas of practical importance to the construction industry. Emphasis should be placed on standardization-related work; on dissemination of advanced technologies through seminars; on joint development and implementation projects; on transfer of foreign technology to the U.S. construction community; and on development of easy-to-use databases for access by industry. The CBT's cooperation with academia is felt to be very good.

The Panel recommends that mechanisms be developed to solicit industrial input regarding the practical applications of the work performed by the Building Materials Division. Such communications would add to the credibility of the Building Materials Division and tend to increase moral and financial support by the construction industry. Although the Building Materials Division does an excellent job in publishing research data and in participating in professional and standardization associations, there is a need to improve the CBT's visibility to increase the practical applications of its work by industry.

Many products used by the construction industry are developed and brought to market very quickly for competitive reasons. Consensus specifications and standards are developed more slowly and can lag the introduction of a new product by 10 or more years. Although the consensus process is essential, the time between the introduction of a new commercial product and the issuance of a consensus standard contributes to numerous quality and durability problems in the field. In order to help bridge the gap between the introduction of a new product and the consensus standard, it would be very useful if manufacturers, specification writers, and end users could obtain interim guidance from a respected organization such as the CBT.

Under this proposal, industry could contact the CBT to request initiation of a research study to review the known and unknown aspects of a new product or technology. The CBT could then issue a research report recommending interim quality levels and defining areas requiring further research. If a state-of-the-art report could be generated within 6 months of a request, then industry would have available a document that could serve as the basis for promoting standards and for justifying further research. Concerned end users could also use this document to assure better quality and durability, until a consensus standard is adopted.

Overall, the Building Materials Division is to be commended for its performance under difficult conditions. The CBT works at the frontiers of an old, conservative technology, and leads the field of construction materials research and development in terms of innovations and quality of work. To be able to accomplish its basic goals, the CBT will have to strengthen its staff, develop new mechanisms for technology transfer to government and industry, and take a more active role in leading construction materials research and development activities of importance to the nation.

Computer-Integrated Construction

Computer-Integrated Construction is a program begun within CBT in 1985 that recognizes the impact of computers in all aspects of design and construction. The present foci of this program are computer-based building code systems and data communications between computer programs used in the building design process. These tasks fall within the traditional role of the CBT.

This program began in an ambitious excursion into a number of research undertakings, and in the past 2 years has retreated, due to budget restrictions, to a limited program focusing on testing and extension of the Initial Graphics Exchange Specification (IGES) for use in architecture/engineering/construction (AEC) applications; development of methodology for data modeling of the more complex data exchange requirements needed in advanced computer-aided design (CAD) systems; automated generation of specifications from textual input; and expert systems as vehicles for delivering building codes.

The testing and extension of data exchange standards for AEC use is a clear responsibility of the NBS and the CBT. The lead role for the development of data-exchange standards has been NBS, through the Center for Manufacturing Engineering (CME). Ideally, CBT should focus on those extensions to IGES needed for AEC use. Unfortunately, even though IGES is required by most federal agencies as an archive format, and is included in the Army Computer-Aided Logistic System (CALS), MIL-Spec 1840A, and other standards, it is well known to be incomplete as an archival standard, even for two-dimensional drawings. No criteria for compliance with IGES have been developed and promulgated. The semantic component of the standard is incomplete. In reality, the archival computer tapes now being collected by federal agencies and private owners are unreadable without significant manual reconstruction.

Because the IGES standard is incomplete, the Computer-Integrated Construction Group has begun to develop test procedures needed to make IGES useful as a data exchange and archival standard. The Panel considers this crucial activity to be of central importance to all users of IGES (and almost all AEC CAD users are IGES users). In light of the fundamental work being done by the Computer-Integrated Construction Group on IGES, the NBS should consider broadening the authority for IGES to include the CBT. The Panel also strongly recommends that the Computer-Integrated Construction Group be represented in the Department of Defense (DOD) CALS program and on the MIL-Spec 1840A activities, both of which include IGES requirements.

The advanced data exchange work, the Product Description Specification, is based on the recognition that there is no common underlying structure for modeling systems for computer-aided engineering and design, and that such a common structure must exist in order to exchange data between computer systems. As necessary tools for defining this structure, general data modeling methodologies are being reviewed for their adequacy to model engineering information. Several dozens of man-years of work will be required before the nucleus of a data modeling methodology will emerge and construction issues can be addressed. The limited resources of the CBT Computer-Integrated Construction Group are not adequate for such an undertaking.

The development of translators that automatically generate tests of building codes is a technology that certainly will be needed some time in the future, but that future is far distant. Several other technologies required for automated evaluation of building designs and specifications for code compliance need to be developed before automatic code test generation can be achieved. Among these required technologies are (1) a standard representation for building design information and (2) expert systems for code compliance checking.

In industry, work is proceeding quickly on design programs that incorporate both design and code checks. These mixed-use programs will not support complete code checking but will be useful during design. This limited form of checking will be incorporated in commercial software products very soon. The Panel expects such commercial expert systems to mix code compliance checking with industrial fabrication practices and other information in ways that may or may not allow code tests to be easily separated from other forms of checking. Commercial software development is moving rapidly and its ultimate form may well be different from that now anticipated. Needed are the means to translate codes for these applications and the means to verify that the checking program is a faithful representation of the written code.

The staff members of the Computer-Integrated Construction Group are very good and some of the junior staff are excellent. The Group has been well represented at technical meetings during the past year and has played an important role in educating computer users and software developers on the issues associated with data exchange and data exchange standards. The involvement of graduate students in the work of the Group is to be commended, but the CBT must be sure that it defines and controls the conduct of the research, to assure that the objectives of the computer-integrated construction program are met.

The Panel recommends that important additional activities should be addressed by the Computer-Integrated Construction initiative. Among these is the development of test procedures for certification of computer-aided design programs so that they may be used in building code checks. A few such programs exist and have been certified by some regulatory agencies. New computer programs are continually being developed that are candidates for certification, but no methodology for such certification now exists. Computer-aided design software certification is urgently needed and would be an appropriate undertaking for the CBT.

The Panel encourages the Computer-Integrated Construction staff to continue its involvement in technical meetings in the construction industry; in addition, the CBT should consider hosting workshops on topics that would promote information coordination in the construction industry. Among the possible topics for such workshops are information modeling languages for CAD specifications; expert system language structures for embedding design knowledge; and building component specification formats for automatic incorporation and use in CAD systems.

The computing facility for the Computer-Integrated Construction Group activities has a small network of workstations that includes PCs, Suns, and Apollos. These facilities are appropriate and adequate for the current and anticipated work.

The Panel is increasingly aware of the overlap between the activities of the CBT and those of the mission-specific laboratories funded by the DOD (including the U.S. Army Civil Engineering Research Laboratory and the Naval Facilities Command) and the DOE (including Lawrence Livermore and the Sandia laboratories). The charters of these laboratories are very different, yet their work and the competition for funding frequently overlap. Greater coordination between these facilities is needed; complementary development of research agendas would strengthen the technical activities and improve efficiency under limited federal budgets. The CBT should take the lead in pursuing coordination with these other agencies.

The Computer-Integrated Construction Group within the CBT is undertaking work that is of crucial importance to the enhancement of productivity and international competitiveness of the U.S. construction industry. Because of the disaggregated structure of the construction industry, the benefits of this research are small to any one firm, yet they may be large to the industry as a whole. The Panel believes that external funding is feasible, justifiable, and essential to the long-term success of this work. Therefore, the Panel recommends that external funding be pursued with such agencies as DOD, the National Aeronautics and Space Administration, and DOE. The Panel is convinced that continued visibility should bring external funding to these important projects in computer-integrated construction.

CENTER FOR BUILDING TECHNOLOGY
RECENT PRIVATE SECTOR SUPPORT

Quality Assurance for Construction Materials Testing Laboratories FY 1929-89). Two long-established Center for Building Technology (CBT) Programs staffed by 33 industrial Research Associate are the ASTM-sponsored Cement and Concrete Reference Laboratory (CCRL), and the AASHTO-sponsored AASHTO (American Association of State Highway and Transportation Officials) Materials Reference Laboratory (AMRL). The two reference laboratories constituting CBT's Construction Materials Research Laboratory (CMRL) provide inspection and proficiency sample services to 800 construction materials testing laboratories which use ASTM and/or AASHTO test methods.

Cementitious Materials Modeling (FY 1989). With the Center for Advanced Cement-Based Materials, a consortium of four universities, (Northwestern and Purdue Universities and the Universities of Illinois and Michigan) funded by the National Science Foundation, CBT is helping develop mathematical models to predict the performance of concrete and related materials and to predict the transport properties of cementitious materials. Also, CBT is investigating factors affecting the flow of dense flocculated suspensions such as cement pastes and concrete. This research will help make concrete a more predictable material and help improve its performance.

Impact Limiter Testing (FY 1988-89). For EG&G Idaho, Inc. and Transnuclear Corporation, CBT experimentally evaluated the deformation characteristics of impact limiters. Impact limiters are used to protect nuclear spent-fuel casks during transit. This research has helped these industries establish safety factors for future designs of impact limiter devices.

Quality of Lighting in Power Station Control Rooms (FY 1989). Under sponsorship of the Lighting Research Center (LRC) and the Niagara Mohawk Power Corporation, CBT is cooperating with researchers from the Rensselaer Polytechnic Institute to determine environmental factors e.g., lighting that influence worker alertness in control rooms of nuclear power stations.

Determining Lighting Quality in Office Buildings (FY 1984-89). Under sponsorship of the Lighting Research Institute (LRI) a Research Associate working at CBT evaluated the impact of luminance (brightness) distribution of workstations in 912 office buildings to determine their lighting quality. This research provided basic data on lighting power densities and photometric measurements in office building.

Lighting-HVAC Interactions (FY 1985-89). Working with the Electric Power Research Institute (EPRI), CBT determined basic design features for lighting and HVAC (heating, ventilating, and air conditioning) systems in commercial buildings that will lead to significant energy savings for the nation. Two private sector design firms, Dubin-Bloome Associates of New York and Ross and Baruzzini, Inc. of St. Louis worked with CBT to incorporate the results into new handbooks for the design professionals. Results show by carefully designing the way in which air is returned from the space through the light fixture to the cooling coils in the building, the lamp surface temperature can be controlled to its optimum level near 38°C.

A Rating Methodology for Integrated Heat Pump - Water Heating Appliances (FY 1988-89). This research was sponsored by the Electric Power Research Institute and the Department of Energy; CBT developed a rating method to predict the seasonal performance of integrated heat pump - water heating appliances. An hour-by-hour simulation program was designed which predicts the annual performance of a generic integrated heat pump - water heating appliance.

Nonazeotropic Refrigerant Mixtures (FY 1987-89). Under sponsorship from the Electric Power Research Institute (EPRI), CBT designed, constructed, modelled, and tested breadboard heat pump systems to experimentally evaluate new concepts that use nonazeotropic refrigerant mixtures. CBT developed a detailed computer model of air-to-air heat pumps with nonazeotropic mixtures for predicting the thermodynamic properties of mixtures. A new laboratory was built for measuring the boiling heat transfer coefficient of refrigerants and refrigerant mixtures in horizontal tubes. A multi-fiber optical probe was developed for measuring void-fraction of two-phase flow and a high speed photography technique was used to study bubble growth during boiling. This research aided in understanding the reason that mixture heat transfer coefficients degrade relative to the respective pure components under similar flow conditions.

Examination of NonAzeotropic Mixture Refrigerants for Heat Pumps (FY 1987). The Electric Power Research Institute sponsored this research to develop a simulation model of a vapor compression cycle operating with binary nonazeotropic refrigerant mixtures and to perform a parametric evaluation of the energy performance advantages of these mixtures for heat pumps. The results of this research were presented at a workshop for worldwide leaders in this field to explore the best path for future research.

Punching Shear Behavior of Ice Wall (FY 1984-87). Under sponsorship of the Minerals Management Service and five oil companies (EXXON, Mobile, SOHO, Shell, Chevron) CBT completed a four-year cooperative research program to evaluate the punching shear behavior of thick lightweight concrete ice walls used in offshore structures. The results revealed the 1. punching shear strength for plate specimens was greater than that required by the ACI code and 2. current ACI code provisions are conservative. These findings are being used by oil companies in their design of concrete offshore structures for the Arctic.

Acoustic Measurement of Attic Insulation (FY 1987). The Mineral Insulation Manufacturers Association sponsored research to study the feasibility of using acoustic techniques to determine the density, thickness, and thermal performance of attic insulation. As a result, a laboratory instrument for measuring sound transmission in loose-filled insulation was designed and produced. This led development of a practical field method for determining the quantity and quality of installed insulation.

Preliminary Performance Criteria for Roofing Felts (FY 1985-87). Under a grant from the E.I. DuPont de Nemours and Company, CBT developed revised performance criterion for the tensile-elongation properties of bituminous built-up roofing (BUR) membranes. The CBT performance criterion is used to select bituminous membrane products on a rational basis, without unnecessary limitations on composition.

CONSTRUCTION MATERIALS REFERENCE LABORATORIES (CMRL)

I. CURRENT ACTIVITIES

September 1988

- LABORATORY INSPECTION PROGRAMS
  - CCRL - Testing of:
    - cements
    - concrete
    - aggregates
    - reinforcing steel
    - pozzolans
  - AMRL - Testing of:
    - soils
    - aggregates
    - asphalt cement
    - bituminous concrete
- PROFICIENCY SAMPLE PROGRAMS
  - CCRL - Testing of:
    - portland cement
    - blended cement
    - masonry cement
    - portland cement concrete
    - fly ash
  - AMRL - Testing of:
    - soils
    - fine aggregates
    - coarse aggregates
    - asphalt cement
    - cut-back asphalt
    - bituminous concrete
- TECHNICAL STUDIES TO IMPROVE STANDARD TEST METHODS
- TECHNICAL SUPPORT TO CONSTRUCTION MATERIAL STANDARDS COMMITTEES

II. BENEFITS OF CMRL PROGRAMS TO PARTICIPATING LABORATORIES AND OTHERS

- improves the reliability of test measurements
- provides data to quantify standard measurement techniques
- provides laboratory inspection and proficiency sample components for use by national laboratory accreditation systems
- provides direct communications between testing laboratories and standards-writing committees

CONSTRUCTION MATERIALS REFERENCE LABORATORIES

CENTER FOR BUILDING TECHNOLOGY

National Engineering Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899

CONSTRUCTION MATERIALS REFERENCE LABORATORIES

The Construction Materials Reference Laboratories (CMRL) is part of the Building Materials Division of the Center for Building Technology (CBT) at the National Institute of Standards and Technology (NIST). The CMRL currently consists of the Cement and Concrete Reference Laboratory (CCRL) sponsored by the American Society for Testing and Materials (ASTM), and the AASHTO Materials Reference Laboratory(AMRL) sponsored by the American Association of State Highway and Transportation Officials (AASHTO). The goal of the CMRL is to promote improvement in the quality of testing of construction materials in the nation's testing laboratories through test method assessment and development, support to the development of National standards, and support to quality control and quality assurance programs. CMRL programs support an objective of NIST "to assist industry in the development of technology and procedures needed to improve quality." The CBT mission to "increase the usefulness, safety, and economy of buildings through the advancement of building technology and its application to the improvement of building practices" is also supported. There is flexibility to incorporate other activities into CMRL which could support this mission in other ways.

The activities of the Construction Materials Reference Laboratories are outlined under the four headings below.

LABORATORY INSPECTION

Inspection of construction materials testing laboratories directly promotes improved quality of equipment and procedures used in the testing of construction materials. Each inspection visit consists of an examination of the apparatus used in testing a material for conformance to ASTM or AASHTO standards and observation of tests being conducted. At the completion of the visit a comprehensive oral report is presented to the laboratory supervisor and a written confirmatory report is subsequently provided. Laboratory inspections are scheduled to cover the United States and Canada in a sequential manner on a recurring basis at intervals of approximately two and one-half years for CCRL and two years for AMRL. Over 300 laboratories are inspected per year.

PROFICIENCY SAMPLE PROGRAMS

Proficiency sample programs provide comparisons of results of standard tests within or among laboratories for the purpose of aiding in the recognition of, and correction of, deficiencies. Uniform samples are prepared from lots of a given material and sent to participating laboratories with instructions for performing the tests. Each laboratory returns the test results to the CMRL for review and analysis. A final report with statistical information is provided to all participants. Over 1500 laboratories participate in the proficiency sample programs.

PARTICIPATION IN WORK OF TECHNICAL COMMITTEES

Staff of the CMRL actively participate in the work of the technical committees of standards organizations such as ASTM and AASHTO. Data from the proficiency sample programs are made available to the working subcommittees to assist in improvement of standards. This provides direct communication between standards developers and users.

STUDY OF TESTING PROBLEMS

Special studies to aid understanding and improvement of standard methods of test for construction materials are conducted to complement other CMRL activities. These studies are often conducted in cooperation with other NIST units.

SPONSORING ORGANIZATIONS

The CCRL and AMRL are Research Associate Programs located at NIST and managed in cooperation with their sponsoring organizations. The CCRL, sponsored by the American Society for Testing and Materials, was established at NIST in 1929 under the sponsorship of Committee C1 on Cement. Committee C9 on Concrete and Aggregates became a co-sponsor in 1958. The AMRL was established at NIST in 1965 under the sponsorship of the Subcommittee on Materials of the American Association of State Highway and Transportation Officials. There are 33 research associates in the CCRL and AMRL programs.

METHOD OF OPERATION

Participation in the laboratory inspection or proficiency sample programs is voluntary. It is initiated by requests from interested organizations who are willing to pay fees established by the sponsoring organizations for the services provided. Neither the CCRL nor the AMRL certify or rate laboratories nor do they serve as referees in disputes concerning quality of materials being tested.

For further information regarding scope of services, schedules, and fees for service, please contact:

Construction Materials Reference
Laboratories
Center for Building Technology
Building 226, Room A365
National Institute of Standards and
Technology
Gaithersburg, MD 20899
Telephone: (301) 975-6704

1989 CBT BUILDING TECHNOLOGY SYMPOSIA

We look forward to your participation in the 1989 Building Technology Symposia Series. The symposia focus on a variety of building technology issues facing the public and private sectors. The symposia provide a forum for identifying problems and a means for translating new knowledge into improved building practices. The symposia are a strong element of our efforts to advance the Nation's building technology and to facilitate its application for the public benefit.

The atmosphere promotes free exchange of views. Speakers are drawn from public and private organizations and from our staff; substantial time is allotted for informal discussions; no minutes are kept. The symposia were initiated in response to an Office of Management and Budget request to promote interagency communication and coordination in the field of building technology. During the past 19 years this forum has been successful in exchanging building technology between all members of the building community. Space generally is limited to 90 persons. Please make your reservations early.

Richard N. Wright

Richard N. Wright
Director
Center for Building Technology
National Engineering Laboratory
National Institute of
Standards and Technology
U.S. Department of Commerce
Gaithersburg, MD 20899

Schedule

Dates	Topic Title
Tuesday, February 14, 1989	Earth Orbiting Structures Lecture Room A - Contact: William Stone, CBT, 301-975-6075
Tuesday, March 28, 1989	Moisture Research Problems in Buildings Lecture Room B - Contact: Douglas Burch, CBT, 301-975-6433
Tuesday, April 11, 1989	Lighting Research at National Building Technology Laboratories Lecture Room B - Contact: Belinda Collins, CBT, 301-975-6455
Thursday, May 4, 1989	Design of Structures for Explosive Threats Lecture Room B - Contact: William Keenan, NCEL[1], 805-982-4822 or H.S. Lew, CBT, 301-975-6061
Tuesday, June 20, 1989	Facility Diagnostics Lecture Room A - Contact: Melvin Hironaka, NCEL[1], 805-982-5196 or Geoffrey Frohnsdorff, CBT, 301-975-6706
Tuesday, September 26, 1989	Communication Protocols for Building Automation Systems Lecture Room B - Contact: Steven Bushby, CBT, 301-975-5873
Tuesday, October 17, 1989	Diagnostics and Maintenance of Mechanical Systems in Buildings Lecture Room A - Contact: Henry Borger, BRB[2], 202-334-3378, Howard Gaberson, NCEL[1], 805-982-5435, or George Kelly, CBT, 301-975-5870
Tuesday, November 14, 1989	Design and Construction Technology for Wood Systems Lecture Room A - Contact: Erwin Schaffer, FPL[3], 608-264-5672 or Charles Yancey, CBT, 301-975-6073
Tuesday, December 5, 1989	Evaluation and Adoption of Innovative Building Technologies Lecture Room A - Contact: Thomas Napier, CERL[4], 217-373-7263 or Geoffrey Frohnsdorff, CBT, 301-975-6706

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[1] Naval Civil Engineering Laboratory, Port Hueneme, CA

[2] Building Research Board, National Academies of Sciences and Engineering, Washington, DC

[3] Forest Products Laboratory, Department of Agriculture, Madison, WI

[4] Construction Engineering Research Laboratory, Department of the Army, Champaign, IL

Mr. WALGREN. And I—I'm also curious as to whether those requests come in the form, not just of requests that you do it, but requests that would be able to cost-shared or what our experiences in—how are these requests coming? Are there possibilities of cost-shared research that we're not engaging in?

That would be very helpful, I think.

Mr. WRIGHT. Good.

Mr. WALGREN. Well, all right, let me thank all of you for being a resource to us. We appreciate your participation this morning and perhaps we'll have some other thoughts that we could ask you to develop with us later on.

Okay, thanks very much.

The second panel, John Eberhard, from the Department of Architecture at Carnegie Mellon University; Tim Killen, Director of Research at Bechtel; and Eric Balinski, a—involved with the Living Environment. If you folks would come forward and join us.

As with the first panel, your written statements and written submissions that you would like to make will be made part of the record without more and you can certainly—I'd like to encourage you to focus on those points that you would like to stand out to people looking just at the oral transcript part of this record, which is separate than the written statements, and in that sense, be able to focus on points that you feel deserve to be underscored in whatever way that you would like to do that.

So let me first welcome John Eberhard.

STATEMENTS OF JOHN EBERHARD, HEAD, DEPARTMENT OF ARCHITECTURE, CARNEGIE MELLON UNIVERSITY, PITTSBURGH, PENNSYLVANIA; TIMOTHY S. KILLEN, DIRECTOR OF RESEARCH, BECHTEL CORPORATION; AND ERIC BALINSKI, MARKETING MANAGER, LIVING ENVIRONMENT

Mr. EBERHARD. Thank you, Mr. Chairman.

I've been doing this for some 25 years and even though I'm an architect and am educating future architects, most of my career has been involved in managing research.

When I first came to Washington in 1963 and went to a hearing very similar to this, the same set of issues were raised, almost entirely with the same set of answers.

I have a slightly different set of answers I'd like to suggest to you today, though, to some of the questions and issues that have been raised.

First of all, there's the question of how much research does the construction industry do and I noticed you asked a number of questions along that line. If the question was broader, that is, where do new ideas come from and where do—and how do innovations get introduced in the construction industry, we find that this industry, say, unlike the space industry or electronics industry, is not research-oriented, but it's not that there are a paucity of ideas.

In the last 100 years, there have been enormous changes in the design of buildings, for example, which I'm sure you're well aware of. When I first went to architectural school in 1948, everybody who studied architecture designed classic buildings, buildings that looked something like this one or like the Capitol building or the

Supreme Court building. Now there is no school of architecture that I know of where one can study the design of classic buildings, to study the design of contemporary buildings.

That change in contemporary design has been the result of innovation by architects in practice. The same sort of thing could be said about structural design. Engineers, in practice, have introduced structural design innovations into design of bridges, railways, structural design for buildings over the years.

People who are craftsmen on the building site constantly are making minor improvements in the way that they go about their construction process. Supervisors of construction introduce modest changes into the way that the construction process is organized on the site. Even government agencies who are customers of the construction industry, by allowing new ideas and innovations to be introduced, create an era—an aura for those new ideas to be tried.

So the point is that there is a large amount of activity that goes on in the construction industry that's not called research in the formal sense, that still allows the introduction of invention and innovation. So while we should be concerned about the small amount of research that goes on in the formal sense, we ought to be as much concerned with the total climate for introducing invention and innovation into the building industry, some of which is related to research as a formal activity.

Having said that, however, there seems to me an idea model for relating research to systems designed—which is represented by one of the major inventions introduced into the building field, into buildings, over the last 100 years, the telephone. The telephone, from its very beginning, has been improved as a total system by research teams that included scientists; it included people from the manufacturing sector who produce the instruments and the equipment, and it produced field engineers—and it included field engineers who are involved in the actual installation.

Those teams have been enormously successful over the last 100 years in making constant improvements in the telephone system of this country. If we had the capability in the construction industry of organizing systems activities of those kinds that addressed the performance characteristics of building systems and urbane systems, then I think we would have a substantially greater leverage on the small amount of research that is supported.

I noticed in the bill that was sent to me in the mail when I was asked to testify, which this committee authored some time ago, August, 1987, bill on Technology Competitiveness Act of 1987, there was a provision in there which I assume has never been carried out, to establish an advanced technology foundation and an advanced technology board.

That concept seems to me to have much merit, and if an advanced technology foundation was created, whose role was to bring together the kind of research that's done by government laboratories with people from the construction industry, it would be the equivalent of the telephone company's producers of building materials, and the people who are in the construction to work on the improvement of whole systems, not just building products, I think we could make some substantial progress.

Those recommendations are contained in my report. If I could just say a few other words about some of the myths that I think in 25 years continue to come up in this industry. One is that productivity is declining. That's not exactly clear at all. It's the result of statistical aberrations in the way that the Bureau of Labor Statistics are combined with the Department of Commerce's statistics on construction volume, both of which are woefully underfunded, both of which have to collect data based on a series of data, rather than current data, and both are, therefore, as both Dr. Wright and someone else suggested, are not really reflecting the productivity of the construction industry in the United States.

I think that's a poor whipping boy to be used by Congress.

The second is foreign competition, and I know that's a major concern. I'm not sure what it means to have foreign competition when architectural firms are owned by Swiss firms, French firms, British firms, when construction firms have operations in 35 places around the world, when one of the largest construction firms in the United States was bought by a German company, where is the United States? I would like to rather see the issue be that, like other industries, the construction industry is now part of a global market, and what we ought to be addressing is opportunities. How does the United States companies participate in that global market and particularly, by 1992, when the European community becomes established as a single market, we ought to be better prepared than we are right now to be participating in the opportunities that that global market situation is going to create for us.

And the last one and one that I know is raised a couple of times with our friend from the Department of Housing and Urban Development, what about the cost of housing? I'm convinced in 25 years having been in Washington working on that problem, there is absolutely, positively no technological solution to that problem. It is not a problem of technology; it is a problem of real estate investment speculation and banking institutions' rules about mortgage availability.

Unless those rules are changed, there is nothing that research and technology in the construction industry is going to do about the cost of housing.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Eberhard follows:]

September 12, 1989

TESTIMONY BY
John P. Eberhard
Chairman
Department of Architecture
Carnegie Mellon University

BEFORE: Subcommittee on Science, Research and Technology
U.S. House of Representatives
Committee on Science, Space and Technology

SUBJECT: Hearing on Research and Development in the
Construction Industry.

Chairman Walgren, and members of the Subcommittee, thank you for inviting me today to speak on the subject of research and development in the construction industry. While I am educated as an architect, have practiced as an architect, and now devote my time to educating a new generation of architects, I have spent a major portion of my career organizing and managing research programs related to the design and construction of the built environment. My research responsibilities have included managing programs within the government,in professional societies, in universities and for the private sector. I believe that I can speak with some authority on the status of research within the construction sector of the United States, and I have considerable knowledge of the research being done by other countries. Because of my work at the National Bureau of Standards (now NIST) and the National Academy of Sciences, I also have a reasonable understanding of research going on in other fields.

While I believe it is clear that research and development as a formal activity of construction related organizations, that is work which is funded and managed by an organizational unit identified as doing research, is small in comparison to most other industries, nevertheless the industries of building are both inventive and innovative. Those of us who have spent our careers in research tend to discount design innovations by architects and engineers as "research". We overlook the informal activities of millions of skilled craftsmen on construction sites who are constantly making small (but often significant) improvements in the processes of construction. We seldom hear about the construction foreman who has devised a better way of organizing work or materials handling at a building site. Construction agencies of governments (federal, state and local) who introduce new ideas into their projects or provide opportunities for innovative products to be tried are not counted as doing research. However, design innovations, small process improvements, better ways of organizing work, use of innovative products all lead to new ideas being incorporated in the processes and products of the building industry.

If we look at the changes which have been introduced into the design and construction of buildings in the past one hundred years, they are considerable:

When I began my architectural studies at the University of Illinois in 1948 we were still being taught to design buildings in the classic styles handed down from Greek and Roman times. By the time I graduated, only four years later, there were no schools of architecture in the United States that still taught classic design. When I began my own architectural practice in 1953, devoted to the design of churches, I was one of the pioneers in introducing contemporary design into ecclesiastical architecture. This revolution in architectural design which has literally changed the physical appearance of the world was not the result of formal research and development, but the introduction of design ideas by architects such as Walter Gropius, Frank Lloyd Wright, Mies Van der Rohe, and Le Corbusier.

The use of structural steel, and later reinforced concrete, as a structural system for buildings and bridges was almost entirely the result of the invention of the Bessemer process for making steel (not an organized research effort) and the introduction by practicing engineers of steel members into a long series of evolutionary improvements in structural design. Today there is a significant amount of research related to improvements in structural design, but the fundamental concepts were introduced more than 100 years ago.

The introduction of indoor plumbing into buildings was the result of a long period of trial and error. The rapid diffusion of plumbing into the building stock of the world at the end of the last century was precipitated by a scientific finding that disease was carried by impurities that crept into water supplies from outdoor privies, but water and sewer systems were feats of engineering - not research organizations.

This same pattern of inventions being introduced into use in buildings by engineering design includes electricity, central heating, air-conditioning, elevators, and escalators. At the urban level the introduction of the automobile (and road systems), subways, trolly cars, and elevated trains were all done without formal research organizations.

There is one major urban invention that is an exception to all of the above..the telephone. From the beginning the telephone was the result of careful research and massive development efforts. Five years after Alexander Graham Bell's careful studies (certainly research by any reasonable definition) resulted in this revolutionary device for carrying messages, the Bell Telephone Company began its long and successful history of using teams of scientists, manufacturers, and field installation engineers to constantly advance the performance of the system. It is this concept of carefully orchestrated research and development efforts designed to improve systems performance that is missing in the construction industry.

Isolated research by a physicist or chemist on the properties of materials becomes useful when it is connected to a larger team effort. New design ideas by architects and engineers become more than interesting art forms when these ideas are precipitated by systems performance improvements generated by improved technologies. Social science explorations of human behaviour in buildings can be sterile academic exercises in the absense of working links with others working on improved performance criteria.

This is a long way of getting to your first questions regarding the role of the Federal Government in supporting research in the construction industry. I suggest the following ground rules:

1. Continue to support traditional research areas of a more fundamental character at places like the Center for Building Technology of NIST, the Army's Construction Engineering Research Laboratory, the Navy's work at Port Hueneme, California, the Air Force work at Tyndal Air Force Base, and the National Science Foundation's support of university research, but recognise that these traditional

areas would be advanced in importance if there were a larger context for utilizing their work, such as the Advanced Technology Foundation proposed in H.R. 2916 in August, 1987..

2. Give new recognition to the cross-over potential from research done in other fields. For example: Work now being done by research organizations in the bio-engineering and biological sciences might well make a major contribution to the management of human waste or household garbage. Work in photonics could well change the nature of utility and communications systems within building. Work in electronics has the potential to make major advances in building safety, the control of comfort systems, and building system responses to use patterns. Such cross-over research is not easily stimulated by the customers of the construction industry since they are so fragmented and consequently small in scale. The National Science Foundation might well be given such a mission, but it is not a natural fit with their traditional role of passively responding to disciplinary interests.

3. Government laboratories could be stimulated to work on such issues for Federal agencies who design and build facilities for the government own use.

4. Better still the Technology Competitiveness Act of 1987 and the Stevenson-Wydler Technology Innovation Act of 1980 could well provide the grounds for national

experimental labs being established around the country for such purposes. Especially if these labs would use the successful model of the Bell Telephone Laboratories to address large scale systems performance with teams of scientists, manufacturers from the private sector, and construction industry personnel experienced with field conditions.

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RESPONSE TO OTHER ISSUES

PROGRAMS FOR TECHNOLOGY DEVELOPMENT

The Committee has asked what type of program structure might best lend itself to cooperative research between industry and government labs, if it were to be supported by the Federal Government. It seems clear that the development of advanced infrastructure for our cities, designed to replace (not just maintain) the existing infrastructure that is now rapidly deteriorating should be our first priority. If these advanced systems were based on new developments in science and technology, and if they clearly were intended to advance the performance capability of cities, the market potential in this country and around the world would be enormous. Buildings are "plugged" into the infrastructure of cities. Consequently, the potential for advances in the performance of buildings begins with fundamental and dramatic changes in infrastructure. At some later date, I would be pleased to expand on this subject if your committee would wish to do so.

FOREIGN COMPETITION

The construction industry of the United States is now part of a global network which cannot be easily defended on a parochial basis. Architectural and engineering firms have sold a portion of their stock to firms in other countries, or have been totaly purchased by international firms. Construction firms have formed overseas branches, or even more often have undertaken joint projects with firms in other countries. Producers of building materials and systems have formed operating arms in other countries. However, there is reason to be concerned with our national posture with respect to construction activities on a global basis. A recent study by the Building Research Board of National Academy of Sciences suggested that, "While U.S. firms have found that cooperation is often more effective than confrontation for maintaining market share (in international markets), they are hampered at home and abroad by what industry leaders perceive to be a persistent national shortcoming of education, research and development. There are pressing needs for the United States to catch up with its rivals in developing the design skills, foreign language capabilities, and cross-cultural sensitivity of our young engineers, architects, and construction managers; for greater and more reliable support of research that can lead to innovation in building sciences and infrastructure technology; and for more assertive leadership in adopting innovation that can enhance domestic productivity and international competitiveness."

PRODUCTIVITY

The issue of productivity and costs in the construction industry tends to be a distortion of statistics. We have no good, up-to-date data on construction costs or construction industry labor content on which to base productivity measures. Until adequate funding is provided to the Bureau of the Census and the Bureau of Labor Statistics, we cannot base national policies on the productitivity series they produce. High costs are the result of real estate market conditions, not construction industry productivitiy or constraints. The recent disgraceful condition of the nation's savings and loan industry is a larger indicator of our problem than building technology constraints.

COST OF HOUSING

Mortgage banking practices are a much large deterent to innovations in the housing industry than building codes, labor practices, lack of automation, or government approvals of new materials and products. Banking organizations are by their very nature conservative (except for some of the officers of the S&Ls that have gotten in trouble) and only a few people are ever able to buy a house, or finance the construction of rental property without borrowing funds. With the large turn-over in housing ownership (on the average of once every four years) and the continuous escalation of housing prices (in most of the country), bankers are more concerned with the "sale-ability" to the next round of buyers than with the present owners interest in innovative ideas. Consequently developers and home builders are reluctant to introduce products or materials that are not likely to be acceptable to the banking community.

SUMMARY

In summary: I have said that the construction industry of the United States is highly innovative when the history of changes is viewed over the past one hundred years, and that this has happened with little or no formal research being done. I have suggested that most research being done by established research organizations contributes to our base of knowledge, but tends not to be well-connected to the organizations which would utilize such knowledge. This, in turn, has resulted in little or no support from construction industry organizations for formal research. I have suggested that the methods used by the Bell Telephone Laboratories, especially in the early part of the century, in working on systems opportunities with teams of scientists from their labs, technical people experienced in manufacturing, and field engineers provides a model for making major advances in the performance of infrastructure systems utilized in cities and buildings in the future. The role of the government seems well defined in the 1987 legislation entitled "Technology Competitiveness Act of 1987" (H.R. 2916) under Title 1, Section 106 which called for the establishment of an Advanced Technology Foundation within the Department of Commerce, and Section 108 which called for the creation of an Advanced Technology Board to replace the traditional Visiting Committee of the National Bureau of Standards.

I have also suggested that issues of foreign competition are largely parochial and should be replaced by national policies which recognize that we are now operating in a global economy in the construction industry. That issues of productivity in the construction industry are clouded by poor statistics from the Federal Government. And, that issues of housing costs are not ones of technology, or productivity, but real estate speculation and mortgage banking policies.

Thank you for the opportunity to testify on this important subject.

JOHN PAUL EBERHARD

Professor of Architecture
Head: Department of Architecture
Chairman: The Architectural Faculty

TEACHING AREA

Urban Infrastructure, Research Management, Design Management

EDUCATION

University of Illinois, School of Architecture: B.S. Architectural Design, 1952
Massachusetts Institute of Technology, School of Industrial Management: M.S. Industrial Management

TEACHING EXPERIENCE

State University of New York at Buffalo, School of Architectural and Environmental Design: Dean, 1968-1973
Massachusetts Institute of Technology, School of Industrial Management: Visiting Lecturer, 1959-1963

PROFESSIONAL EXPERIENCE

Executive Director, Building Research Board, National Academy of Science-National Research Council, Washington, D.C., 1981-1988
President, AIA Research Corporation, Washington, D.C., 1973-1978
Dean, School of Architectural and Environmental Design, State University of New York at Buffalo, 1968-1973
Director, Institute for Applied Technology, National Bureau of Standards, 1966-1968
Visiting Lecturer, School of Industrial Management, Massachusetts Institute of Technology, 1959-1963
Consultant, Sheraton Corporation of America, Director of Research, 1959-1963
President (and one of the incorporators), Creative Buildings, Inc., 1951-1958

PUBLICATIONS
(Selected)

"The Management of Design in an Industrialized Building Industry," unpublished Masters Thesis, Massachusetts Institute of Technology, June 1959.
"Horizons for the Performance Concept in Building," Proceedings of the First Conference on Performance Concept, Chicago, Illinois, October 1965.
"Technology for the City," International Science and Technology, No. 57, September 1966.
"Management of Design," AIA Journal, October 1968, pp. 80-81.
"The City as a System," in Beyond Left and Right, Radical Thoughts for Our Times, edited by Richard Kostelanetz; William Morrow & Co., Inc. (New York, 1968), pp. 161-166.
with Abram Bernstein, "A Conceptual Framework for Thinking about Urban Infrastructure," Built Environment, Vol. 10, No. 4, Oxford, England, 1984.
"Technology and the Future City," published in the transactions of Lambda Alpha's International Biennial Congress of October 1985.
"Building the City of Tomorrow," published in OUTLOOK section of the Washington Post, June 22, 1988.

MEMBERSHIPS

Fellow, The American Institute of Architects
Member, The Cosmos Club, Washington, D.C.

ACADEMIC AND PROFESSIONAL HONORS

Alfred P. Sloan Fellowship, Massachusetts Institute of Technology, 1959
Engineering News Record Citation as Construction Industry Contributor, 1970
Who's Who in America

RESEARCH

Managed more than 400 projects at: MIT, Sheraton Hotel Corporation, The Institute for Applied Technology, State University of New York at Buffalo, AIA Research Corporation, Building Research Board

SERVICE

Editorial Advisory Committees of more than one dozen journals, 1966-1988
Chairman, Montgomery County, Maryland, Waste-Water Treatment Study, 1984
Vice Chairman, Research Foundation, American Consulting Engineers Council
Consultant to AIA Vision 2000 Program

Mr. **Walgren**. Thank you, Mr. Eberhard.

Since we both come from Pittsburgh, I can't remember—or I can't help but think when we talk about HUD and affordable housing and mobile units and what-not, those units up behind the Civic Arena that—I forget—what was it, Alcoa or one of the metal—it might have been U.S. Steel, but they had metal walls that were experimented with, I guess, and I doubt if they went any further than that, but I often think of them because I was in them one time and sort of sprung the walls around 30 years ago and it stuck with me. But I think there's much in what you say that the problem of—of affordable housing, per se, is probably not technology.

Mr. **Eberhard**. I recently moved to Pittsburgh, Mr. Chairman, so I don't know that. I lived in Washington most of my career. And in the Washington Post two years ago, there was an interesting article which broke down the cost of a typical suburban house in the Maryland suburbs, the Washington suburbs, that was selling at that time for $200,000 and had all of the items, that long list of items.

One of those items was the cost of carpentry and labor. Seven thousand dollars. So I'm quite sure that even if we made those houses—the walls that cost nothing—if we completely eliminated carpentry labor, which, of course, is not technically feasible, that $7000 would not be passed onto the consumer. It would simply be pocketed as an increase in the profits under the distribution of overhead and the house would still sell for $200,000.

Mr. **Walgren**. When was that article in, do you know?

Mr. **Eberhard**. I would say it was about two years ago.

Mr. **Walgren**. Two years ago.

Mr. **Eberhard**. I could try to find it if you—

Mr. **Walgren**. If you have it, we'd love to have it and maybe we can make our own little inquiry to the Post and I'm sure they have ways to retrieve that sort of thing.

Well, let's turn to Mr. Killen.

Mr. **Killen**. Thank you, Mr. Chairman, and thank you for this opportunity to address this subcommittee.

I will be summarizing my written testimony and at the end of my oral testimony, we would like to show the videotape, "Construction 2000."

As you have pointed out, the construction industry is an important industry and a large industry with $400 billion per year. It's now facing intense competition and reduced market share. There are many studies, existing studies, that address this problem and provide sufficient data and information and background. What we recommend now is that the Federal Government establish a group that can put together a five-year action plan.

Now, I will talk a little bit later about that action plan that would identify new tools, new automation needs, new robotics, new research and development that's required to put this industry into a leadership position of international competition.

Now, there are many factors involved in competitiveness, but one intensifying factor that's apparent to us is the increasing technical capability of foreign firms. Other countries are putting more into the construction research and development. They are backing longer-range research ideas and efforts and they are encouraging the results of this research to be placed into the job site and into the projects.

Currently, it is foreign companies, and not American firms, that are leading in technologies like tunneling and like construction automation and robotics. For example, in Japan, each construction company, or the largest construction companies, have their own campus-like, state-of-the-art test laboratory facilities. Also, they have R&D staff that develop hardware and tools and software for the basic construction functions, like placing concrete, tunneling machines, robots for spraying insulation and robots for finishing the concrete surface.

Now, U.S. companies don't have research institutions and laboratories like campus-like facilities, nor do they have technical staff that are working on state-of-the-art robotics. Nevertheless, we're not sitting still. We are moving ahead in many areas and, for example, the U.S. companies really have a leadership position in computer-aided design and the engineering, three-dimensional modeling, data base and project management. We must maintain that leadership.

There are other private research organizations that are helpful along these lines. For example, the Construction Industry Institute for the Center for Integrated Facilities Engineering, the CII, Construction Industry Institute is at the University of Texas in Austin. CIFE is located at Stanford and these are very promising groups of academic institutions and industry to move ahead research in these activities.

Now, the role of the government is important, but limited in a few areas. The NSF funding has been a good source for our industry. The Lehigh ATLSS Center for Advanced Technology for Large Structural Systems is an important group for us. The new CPAR construction productivity advancement research is an important new area to—for cooperative research and the NIST activities in graphic standards, exchange standards, are important.

The government can help by expanding the research at universities like the National Science Foundation has done, helping to set these data exchange standards and encouraging the groupings of industry and government together to pull together in these important areas.

Now, we have sufficient background and data and information in these studies. What we need to do now is put together an action plan and we're recommending a five-year plan. This plan would include specific robotic tools that we need, CAE, computer-aided engineering, simulation, data base requirements and systems for basic construction processes. The plan would include a schedule and estimated cost, resources that are available that we could use.

Such an approach would be an important feature to get us ahead in this area.

Now, I would like to introduce the "Construction 2000" videotape. This was recently developed by Bechtel to provide a vision of the future. It shows a future job site with emerging technologies. Many of these technologies are partially funded today by government sources. It gives us an idea of what is possible and what we can accomplish in the future.

[The videotape, "Construction 2000," viewed.]

[The prepared statement of Mr. Killen follows:]

TESTIMONY OF

Timothy S. Killen

before the

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

of the

U.S. House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

September 12, 1989

INTRODUCTION

Mr. Chairman, my name is Timothy S. Killen, and I am Manager of Engineering and Construction Technologies in Research & Development of Bechtel Group, Inc. My company and I very much appreciate this opportunity to appear before this Subcommittee on the subject of research and development (R&D) in the engineering and construction (E&C) industry.

Domestically, construction is one of the largest sectors of the U.S. economy, employing more than 5 million Americans. New construction in the U.S. accounts for nearly 9% of the gross national product, about $ 350 billion. International contracts have also been a substantial, but diminishing, part of total revenues of E&C firms.

Today, with the shrinking world market, the U.S. E&C firms are facing intense competition from increasingly competent foreign E&C firms armed with new technologies. To be competitive, U.S. engineering and construction firms must take the lead in developing new approaches to construction. We must aggressively seek and adapt technologies from other industries and from foreign firms.

Two recent studies[1] show that E&C companies are losing technological leadership as other countries invest more in research and development. While these studies are adequate in background, data, and problem description, they do not provide an action plan that defines requirements for leadership. Therefore, I recommend that the Federal Government establish a group to develop a five-year action plan. The plan would identify required development -- new tools, advanced equipment, new software, and construction methods/systems -- and resources necessary to accomplish the development.

BACKGROUND

The need for research and development in the American engineering and construction (E&C) industry is an issue of considerable interest in private, government, and academic organizations. Having experienced, in this decade, a significant business decline in our international market and increasing competition from foreign E&C companies, we must more actively analyze competition and look for areas to improve.

There are many factors contributing to the business decline in the international E&C market, not the least of which include; decreased construction in the Middle East and LDCs, restriction of competition in certain foreign projects, foreign government financing subsidies and low-cost loan availability, and lower overseas wage scales in certain countries.

However, there is another important and intensifying factor which cannot be overlooked -- the increasing know-how and technical capability of foreign competitors. This technical capability includes managerial expertise as well as engineering skill, acquired through experience, training, education, and research and development. Other countries, with the support of their governments, are putting more effort into construction research and development, backing longer-range research efforts, and actively encouraging the adoption of useful research results to bring innovation to the construction industry.

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[1] Office of Technology Assessment, *International Competition in Services*, OTA-ITE-328 (Washington, D.C: U.S. Government Printing Office, July 1987), Ch. 4 -- International Competition in Engineering and Construction

National Research Council, *Building for Tomorrow: Global Enterprise and the U.S. Construction Industry*, National Academy Press, Washington, DC, 1988

U.S. companies have an excellent and deserved reputation in engineering, construction, and project management. They also retain a lead in managerial expertise -- which remains a significant though diminishing source of advantage, given the shift in the market away from megaprojects. In technology, U.S. firms lead the world in computer-aided design and engineering (CAD/CAE) and project management systems.

Currently, however, it is foreign companies, not American, that have the lead in fields like tunneling, some applications of new materials, and construction automation/robotics. Overseas firms -- especially the Japanese -- do much more research on basic construction processes. The Japanese construction companies, e.g.; Taisei, Shimizu, Takenaka, Ohbayashi, Kumagai Gumi, and Kajima, have created extensive R&D facilities or Technical Research Institutes. Facilities include structural, environmental, clean rooms, ocean and hydraulic, geotechnical, and new material testing equipment and laboratories. (These facilities are described in various studies and papers[1].) With these facilities, Japanese construction companies have in-house access to advanced and effective tools, and trained technicians for innovative "new idea" and verification testing, or for trouble shooting problems that arise on projects. American companies do not have similar test laboratories. Whenever testing is required, American companies must contract with university or government laboratories.

Also the Japanese construction companies aggressively develop hardware/tools and software for basic construction functions at the jobsite including: Abrasive Sand/Water Jet System, Shield Wall System, tunneling machines, steel structure fireproofing robot, concrete placing, finishing, grinding and cleaning robot, exterior wall painting robot, etc.

Each Japanese construction company has an active development team for construction robotics. This staff performs robot systems's design, prepares specifications for components, supervises manufacturing, performs tests, and develops programming. Development to-date has been on single purpose machines for simple but repetitious construction work. These engineering teams continually improve robot performance by fielding new generations of improved machines.

Although Japanese firms admit that many of the new robots are not currently cost effective, they nevertheless continue to refine them and adjust the design to accommodate and improve the functionality and ease of use. They appear to have a much broader goal, beyond stand-alone robots, to cooperating systems for more integrated design and automated assembly. An important by-product of robot experimentation, is the education of design and engineering impacts, the necessary accommodation early in a project, to make efficient use of robot technology.

In contrast, American E&C firms typically do not have in-house robot development teams. With the exception of laser-guided grading, nuclear plant maintenance, Three Mile Island cleaning, and hazardous waste site characterization there is very little development and experimentation with construction robots.

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[1] Halpin, Daniel W., Final Report, Task 3, *Technology in Architecture, Engineering, and Construction*, OTA Contract No. 633-1970.0, Washington, DC, March 17, 1986

Albus, James S., *Summary Trip Report*, Robot System Division, National Bureau of Standards, July 7, 1985

TECHNOLOGY IN CONSTRUCTION

New technology is likely to be a major factor in future competitiveness as advances in computer technology, expert systems, telecommunications and information processing create a new era in global information technology. Engineering workstations combined with management tools such as computerized inventory and material control systems, together with automated construction equipment and systems will have significant positive impact on costs, response time, and productivity.

Glimpses of future potential are being realized today with application of three dimensional computer design systems that automatically check the design of complex facilities and avoid costly interferences. Bechtel has developed proprietary 3D design, engineering, animation, and management systems which are widely used on all types of projects and are already providing significant advantages. When the 3D computer model is fully integrated with analysis, planning, scheduling, procurement, construction equipment/robotics and systems, and vendor fabrication, the E&C industry will achieve significant advances in cost reduction, improved quality, and faster production. Currently, U.S. firms have a leadership position in CAD/CAE and project management software development and implementation. It is important that this competitive position be maintained by continual improvement and extension into more construction functions. This appears to have U.S. corporate commitment, evidenced by ongoing and increasing U.S. firm development and enhancement of these software applications.

Bechtel actively supports internal development of technology and innovation: Our Chairman, Mr. Steve Bechtel, Jr. states. "We will remain a leader in the development and use of high technology and stay at the leading edge of computer/automation/telecommunication applications in our business." Bechtel, unique in the industry, supports a 115 person Research and Development organization and many other development teams throughout the regional offices. These groups are active on new technology projects involving solar energy, advanced nuclear power plants, robotics, emission control, geothermal and desalination plants, accelerators, knowledge-based systems, computer graphics, animation and simulation, etc. Many Bechtel-developed systems and tools in engineering and management software automation are recognized worldwide for innovation, functionality, and ease-of-use.

PRIVATE RESEARCH ORGANIZATIONS

In addition to private company internal investment in R&D, there are two outstanding U.S. examples of research without direct government support: The Center for Integrated Facilities Engineering (CIFE) at Stanford University and the Construction Industry Institute (CII) at the University of Texas. Bechtel is a charter member of both the CII and the CIFE.

The CII has more than 75 organizations representing owners and contractors, as well as 30 academic institutions, who have combined resources to tackle advanced construction research. The mission is "to improve the cost effectiveness of the construction industry, thereby strengthening the competitive position of American industry in the international marketplace." The Institute believes that improvement is made through research. The organization is broad-based, focusing on thrust areas of research including: technology, organization, people, information, and controls. Twenty-four task forces currently lead research projects in these thrust areas. The Technology thrust area includes six task forces involved in study of automation, robotics, CAD/CAE, and modularization. Present research in CII is mainly study oriented -- it does not produce production systems, software, and robot tools.

CIFE is a partnership between Stanford University and private industry, including international and Japanese construction companies. The goal of this unique, collaborative effort is twofold:

- First, to develop computer-based tools and educational curricula that will encourage better integration of the E&C industry
- Second, to provide both new direction and a "hands-on" training ground for teaching and research programs that will address vital concerns to the E&C industry.

The CIFE technology and research thrust areas include robotics, expert systems, 3-dimensional CAD/CAE, database, and the integration of these components into the E&C process. Japanese companies, generally lagging in implementation of the computer technologies, are very active participants in CIFE including the placement of visiting fellows at Stanford to work on relevant research projects.

ROLE OF GOVERNMENT

Direct government involvement in construction research is limited but important in a few areas. The National Science Foundation (NSF) has been a source of support for university-based research activities for the U.S. design and construction industries. Through the NSF, the Center for Advanced Technology for Large Structural Systems (ATLSS) has been established at Lehigh University. We are participating members of ATLSS and value the potential research accomplishments in the field of structural engineering. We think this center is an important model for broader academic-private industry collaboration on critical construction technologies.

Recently, the U.S. Army Corps of Engineers initiated the Construction Productivity Advancement Research (CPAR) program. CPAR is a cost-shared partnership between the Corps and the U.S. construction industry to facilitate research and development of advanced technology. We support this program, have submitted candidate research proposals, and encourage quick resolution of funding issues in Congress so that this program can get underway. The research products will benefit both private and government engineering and construction.

The National Institute of Standards and Technology (NIST) Center for Building Technology is conducting applicable research on a diverse range of topics. Of particular importance there is the work on CAD database exchange standards such as Initial Graphics Exchange Specification (IGES), the Product Data Exchange Specification (PDES), and the dynamically stabilized platform crane. We need the exchange standards to provide easy data transfer among diverse computer hardware/software systems owned by different project participants, e.g., architect, engineer, fabricator, and contractors. The crane research will help us automate equipment/component installation at the jobsite.

The Federal Government can play a significant role in the following important ways:

- Support and expand E&C related research at universities through the NSF. This can take the form of new National Engineering Research Centers or direct grants to university researchers.
- Help set data modeling and exchange standards in collaboration with industry and universities. This includes the AEC model of PDES. This work is currently led by the NIST, but is proceeding too slowly.
- Encourage integration and discourage fragmentation by supporting more design-and-construction work for government agencies. Many times government contracts are structured such that engineering must be performed by a different company than the construction. The efficiencies of integrating the two functions are not available.

- Increase shared research programs that involve government organizations, universities, and private industry. Structure shared programs where private industry can choose appropriate R&D projects and actively participate in the research.
- Implement "showcase projects" that demonstrate new technologies and new contracting methods. Require the use of CAD/CAE tools and encourage development and use of other advanced automation and construction robotics. Only through experimentation and use in real production environments do we obtain the necessary feedback for improvement of the products and systems.

A VISION OF THE FUTURE

Recently, Bechtel planned and led (for the CII) the 6th International Symposium on Automation and Robotics in Construction. As part of the Plenary Session, I made a presentation on the State of the Art in North America. After addressing the current situation (in construction robotics), I showed a videotape, developed by Bechtel called "Construction 2000." This video (a copy accompanies this testimony) provides a picture and animated vision of what is possible in the future through collaboration on construction R&D. The video simulation combines and integrates several important new technologies currently under development. Included are R&D projects partially funded by government sources, including:

- The advanced beam-to-column connection by Lehigh University in the NSF ATLSS Center
- The Pipe Manipulator by University of Texas partially funded by an NSF research grant
- Advanced automated control of earthmoving equipment. Development could be accelerated and pushed by government funded environmental remediation projects
- The dynamically stabilized platform crane being developed by NIST

This simulation video displays a small subset of possible technological development for U.S. E&C firms. Much more investment and joint cooperative R&D among government, industry and academic institutions is needed for achievement.

NEXT STEPS

We have adequate studies, background data, and problem description as cited in the references. We need to be more specific on industry R&D needs; therefore, I recommend that the Federal Government establish a group to develop a phased five-year action plan. The group would include representation from private industry, government agencies, and academic institutions. With its broad representation and capable staff, the CII could be an effective organization for leadership of such a group.

The action plan would initially identify specific research and development requirements in the following areas:

- Specific construction automation/robotics tools
- CAE, simulation, database software integration
- New materials and standards

- Systems for basic construction processes

The plan would provide a schedule for development of proposed tools and systems. It would also suggest implementation incentives including adequate training of workforce and accommodation for testing. In addition, it would estimate costs and payback opportunities in productivity, higher quality, faster production, improved competitiveness, etc. The plan would identify U.S. R&D resources, i.e.; laboratories, researchers, and organizations, and propose a structure for implementation.

Such an approach would play an important role in sustaining our technological leadership, a necessary condition for an internationally competitive and vital U.S. E&C industry.

Mr. Chairman, we again thank you for the opportunity to share ideas on an important subject to the United States. We hope our comments will be helpful to the Subcommittee's ongoing study of the E&C industry.

Mr. **Walgren**. That's nicely optimistic. Okay.

All right, let's turn to Mr. Balinski.

Mr. **Balinski**. Thank you for giving us the opportunity this morning, Mr. Chairman, to address this subcommittee. Also with me today are Mark Tilley and Joe Reed, from the General Electric Plastics.

What we thought we'd do today, rather than talk specifically about some of the challenges that have been already outlined by the previous speakers, is to describe what we've seen and what we've been doing over the past three years and state we've recognized these as substantial challenges to not only the construction industry, but the U.S. economy. It was interesting—I skim-read Dr. Wright's written presentation. I notice he made reference to a round table back in May, '86, which became the feature story of an Engineering News-Record in July, '86. I would submit this as additional court testimony which substantiates the challenges facing the U.S. construction industry..

[The Engineering News-Record report follows:]

Mr. Walgren. That's nicely optimistic. Okay

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Bringing together experts on construction technologies and what's needed to make them grow, a roundtable at New York College of Technology in Utica was co-sponsored by ENR and the Center for Building Technology of the National Bureau of Standards. Rep. Sherwood Boehlert (R–N.Y.) keynoted the discussion.

To keep America competitive

Technologies need developing–What, how and by whom?

I believe the U.S. construction industry is entering a critical period that could either make or break it. New technologies hold the promise of building better and more profitably, but the growing number of foreign competitors threatens the viability of America's construction industry.

This predicament is not unique to construction. It affects the entire American economy, from smokestack to high-tech industries. But the construction industry is particularly crucial, and its structure makes it more precarious.

It's difficult to think of an industry that is more basic to our economy and to our daily lives. We live and work in its production; it creates our environment. Any threat to the construction industry threatens all of our economy.

And the industry is threatened. American firms are losing business to foreign competition both at home and abroad. Between 1980 and 1984 the share of international contracts won by U.S.-based firms declined from 41 to 31%.

This slippage is not the result of some cyclical downturn that we can simply wait out. We have more and more competitors and they are more and more sophisticated.

Congressman Boehlert
His House committees: Science and Technology, Public Works and Transportation.

The danger is heightened by the structure of the industry. Unlike other basic industries, construction is composed of a myriad of small companies. Partly for this reason, construction companies—those involved in any phase of construction from design to completion—historically have invested very little in research and development.

Yet the keys to the future of American construction are R&D and new technologies to construct new kinds of projects. Other nations are doing that R&D. In 1980, Japanese construction firms spent about $120 million on research and development, and their government and universities spent a multiple of that.

How are we going to compete? Where is the money for R&D going to come from? Who will conduct the research? Obviously, business, labor, academia and government are going to have to work together.

Let me talk about the government's role. The federal government should act as a prod, funding basic and some applied research, providing central facilities and, in general, pressing forward research initiatives that, while vital to the industry, have no immediate payoff.

This is, to a large extent, exactly what the government is doing right now, but we need to double our efforts.

The single largest institution for construction research in this country is the Center for Building Technology at the National Bureau of Standards.

Its benefits to the public are substantial. For instance, the National Association of Home Builders predicts savings of about $500 per home from modifications of plumbing standards based on research at the center. If you think about that $500 per home and then multiply it by 1.8 million—the number of housing starts in America this year—

you are talking about nearly $1 billion in savings from that research.

The center's budget has remained almost constant for five years. To me, that is a source of embarrassment. Even worse, for each of those years the Reagan administration, I am sad to say, has proposed eliminating the center. Administration officials claim that private industry can and should pick up the center's work and that construction research is not part of the mission of the National Bureau of Standards. The administration is wrong on both counts. I fought that proposal, as did others. We have succeeded in saving the center. Private industry and other federal agencies already contribute about $8 million a year to the center, toward its total budget of $12 million. In addition, the construction industry conducts its own research. For example, the National Association of Home Builders Research Foundation, in cooperation with major appliance and equipment manufacturers, is developing a safer, more functional house through a project it calls the "smart house."

The Construction Industry Institute, funded by the private sector, is financing research at colleges and universities to improve construction management.

The Center for Building Technology is not the only part of NBS working on projects of benefit to construction. The Center for Fire Research, which the administration also has tried to extinguish, conducts basic research on materials and computer modeling. The Automated Manufacturing Research Facility is developing interface standards for robots. These engineering research centers are perfect models of how government, industry and academia can cooperate to define problems and invest in research to solve them.

The government's role needs to be examined. Are we doing enough? Are we undertaking the correct projects? Congress has to hear from the experts before we can set policy intelligently.

The better to compete

Richard N. Wright
Roundtable moderator and director of the NBS Center for Building Technology

Wright: Our purpose is to define actions that should be taken by the construction community—the private sector, educational institutions and government—to assure a healthy U.S. construction industry. Our purpose is to understand the technical issues that are important to the health of the U.S. construction industry, to see if we can identify some small number that need special attention and to come up with ideas for working together on those.

Peck: In homebuilding, if the technological efforts can be focused on delivering superior quality, rather than focusing on first cost, we'll make more products. Doing it right the first time in the homebuilding business could save $8,000 to $10,000 per house. So, focusing on quality is in the long term the way to get lower-cost housing.

The Ryland Group welcomes foreign competition. We know it will teach us things. Further, we think it will expand the market for us.

Dellbridge: As deputy chief of the Army Corps of Engineers, I'm one of those guys who goes before Congress to try to get bucks. We are owners, and we have several concerns that all owners would have—cost, timeliness, quality.

Our Department of Defense participates wherever it can in construction R&D. The Army alone operates the Construction Engineering Research Laboratory at the University of Illinois; the Waterways Experiment Station in Vicksburg, Miss.; our Cold Regions Research Laboratory in Hanover, N.H.; and our topographic laboratory, outside of Washington, D.C. We do research for other agencies and share technology with industry. Technology transfer is one of the best things we can do.

Sangrey: Ted Peck mentioned quality. That is the single major reason the Japanese are bringing robotics into construction. It is not labor savings. It is not cost savings. It is primarily quality. Their strategic plan is as clear as a bell for their construction industry—same as it was for their Toyota. They are going to produce higher-quality construction projects and get entree to our markets. Then they will raise prices.

Cardwell: At a recent conference of some 200 executives, several people expressed the same concerns Congressman Boehlert described: the extremely competitive business they are in—not only from domestic competition. They say that on job after job there are foreign competitors.

King: In addition to being in government relations, I am chairman of the executive committee of the National Institute of Building Sciences. NIBS, too, is studying the threat and the impact of foreign competition.

Carlisle: Coming from the installing end of this business, I am struck by three things: involvement, quality and life-cycle costing. If we're going to have

Michael S. Bertino
Vice President eastern region of contractor Mellon-Stuart Co.

H. Keith Cardwell
Construction marketing manager for IBM Corp.

L. Gerald Carlisle
Secretary-treasurer, International Union of Bricklayers

William H. Connolly
Deputy Director, Division of Housing and Development, State of New Jersey

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transfer of technology, there has to be more involvement of individuals who are going to be installing products at the jobsite and of the contractors they work for—particularly the small contractors, who do the majority of the work.

Concerning quality, it isn't enough to change things in building just because they cost more. We need a clear indication of higher quality and efficiency. The new methods have to do a better job for the people who are going to be living and working in a building.

On life-cycle costing, it is important to make the public think more about it. We need a stronger emphasis on the total cost of a building—from the very beginning of the process until until you tear it down.

Connolly: A perspective on the cost of housing: In New Jersey, the cost of housing has risen 25% faster than personal income in the last 10 years.

Masters: There has to be a return to simplicity and proficiency rather than glitz. A lot of things we really don't need cost an awful lot of money. We must get back to the basic premise of performance.

Bertino: We continue to use old methods that are inefficient and ineffective. Clients constantly push contractors for completion on time with high quality, but always at the lowest cost.

Meehan: With changing technology, when something new doesn't work in the field, that's where the buck stops. We specialty contractors are the people who do the installations, and others keep changing things. Also, it's always fast-track, and when you finish and give the guy the bill, he has a heart attack.

Stephan: We need to admit that technological advance is going to involve failure along the way; that's how technology advances.

Jortberg: I think we have to put the need for technology in perspective. Those of us losing jobs in the international markets are not necessarily losing them on the basis of technology. We're losing them for other reasons: Foreign governments support their construction firms through direct subsidies, tax structures and project financing.

There is a risk that those deeply concerned will say that these issues must be dealt with first and that technology can wait. But other countries are moving ahead in the area of technology as well. If we decide as an industry that it's OK to address these things serially, by the time we think we have solved the first problem, we'll be so far behind the eight ball on the second that we will probably never catch up.

So, we should discuss technological needs with an understanding of the economic issues.

Evans: Perhaps we should be thinking and talking about construction technology for the next century. We probably already have the construction technology for the '90s.

Bertino: There is a short-range problem: Architects, engineers and contractors need to use current technology effectively and efficiently to compete. Then there is the long-range problem of evolutionary or revolutionary moves to new technologies, so that 40 years from now we are not building the same way.

Barriers to progress

Evans: I have been working on industrial robots for close to 15 years. One of the areas we are particularly interested in is construction. The industry needs better field inventory control, scheduling procedures and control of manpower resources. But there is practically no interest in more advanced technologies, particularly robotics. There is no market demand. As a result we're turning our attention elsewhere.

Ehrenkrantz: Market forces that can make it worthwhile to invest in new technologies change as the economy has its ups and downs. When new things are developed and ready for use, the interest rates may have gone up, the market changes and we don't use the new technology.

Also, today we have a litigious society, and the risk of working with things that are not tried and true is so great that it puts those introducing new things under very high and undesirable levels of jeopardy.

Masters: Why should I try a new product that looks good but hasn't had 20 years of working experience? We did more pioneering 20 years ago than we're doing today, and the only reason for this regression, in my opinion, is potential liability. We have got to solve that problem.

Connolly: We have seen over the last 10 to 12 years that regulation can either drive or retard technology. Energy conservation is an example where the regulatory system was on to an idea that was appropriate for regulation. Energy codes emerged quickly. But in another area, the introduction of premanufactured technology into construction, our regulatory system, our decentralized system, retards technology—and our ability to meet competition from overseas.

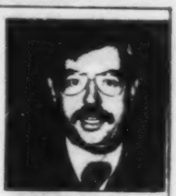
Geissler: One of the biggest concerns we have is the disincentive of the regulatory climate. The legislative and political climate discourages, if not openly prevents, new technologies from being developed or applied.

Masters: We have had a lot of panic legislation. We need a better line of communication between the designers and the regulators who, in essence, control the products. Unfortunately, we have some incompetent, well-inten-

Maj. Gen.
Norman G. Delbridge Jr.
Deputy Chief, Corps of Engineers

Charles M. Eastman
President, FORMTEK, producer
of data management systems

Ezra Ehrenkrantz
The Ehrenkrantz Group,
architects and planners



John M. Evans Jr.
President, Transitions Research
in robotics and automation

[illegible]
Executive Vice President of [illegible]
[illegible]

[illegible]
Executive Director,
Intelligent Buildings Institute

James E. Hill
Building Equipment Division,
Center for Building Technology

Robert F. Jortberg
Recently retired president
of Lummus Construction Co.

tioned people regulating things that they don't understand.

Stephan: One of the major ways that new technology and techniques are introduced in the industry is through the consensus organizations, and they have some very severe handicaps. They are volunteer organizations relying on donated time and effort.

We have been working since 1982 on revising tolerances for concrete construction. Very, very frustrating, and not at all responsive to market needs for introducing that new technology. Yet, code bodies don't accept something until it's been through the consensus process.

MacFayden: We have a fundamental adversarial relationship with government agencies on inspection and permitting. One way to smooth that relationship is to have feedback for identifying the institutional mechanisms that present problems.

The things that go wrong in the regulatory process don't officially feed back to those in the design stage. They may feed back to the contractor because he may bear significant costs, but we need a much stronger feedback mechanism and a much more cooperative environment.

Connolly: It's interesting that the person who offers an opinion on that subject represents NAHB.

Having sat on the cop side of the table for 12 years now, it's been my experience that the input into the regulatory process from all sectors of the construction industry is absolutely dismal. I am not sure I have ever been influenced by comment from an architect or from an architectural organization. Maybe once from an engineering organization.

There is a reason for that. All of our buildings, with the exception of housing, are built like Italian race cars. They are hand-made with no two the same. Also, the project team is never the same. It's the exact opposite of industrialization. Our building teams are constantly getting to know one another. They just barely begin to know one another and they all scatter to the winds and get put together in some other combination for another building project.

Homebuilding is different; it tends to be vertically integrated. Architects and engineers are generally subordinate in their relationship with homebuilders, and the homebuilders tend to work repeatedly with fixed groups of subcontractors.

It's an important thing to understand. We have to make some changes in the way we approach construction if our industry is going to learn and grow and take advantage of technology.

Masters: I don't totally agree. I think a lot depends on the cast of characters. As difficult as New York City is to deal with, it perhaps is one of the easier places to effect a code change; a dialogue of responsible people can be established. Chicago is very difficult. But there are ways of dealing with code changes in Chicago. The major cities, interestingly enough, appear to be the easiest ones to deal with, the easiest places to convince a responsible building official that the code is improper, at least for that project. You can go the variance route if the arguments are compelling enough. It's not easy. It is, in fact, a pioneering effort.

Jortberg: A fellow asked me if I know what pioneers get. The answer: Arrows in their backs.

MacFayden: If it's not easy, you don't get small-scale change. You have to have a revolutionary change with an enormous economic benefit to the promoter to make it. We spent more than $1 million changing the National Electrical Code, looking for a really big payoff. It means that little changes that could otherwise accumulate to create

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Committee of NIBS

Frederick Krimgold
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President, NAHB Research
Foundation Inc.

Richard E. Masters
Partner, Jaros, Baum & Bolles,
mechanical engineers

major improvements are precluded by those regulatory environments.

Connolly: You can get a variance on your building. That illustrates the point I was trying to make: Because of the fragmented nature of the industry, it makes sense to solve the problem for yourself. The stakes aren't high enough for you to make the kind of investment that would solve it for everybody.

You get a slightly different perspe tive from the homebuilders, who a more willing or more able to make th effort on behalf of their entire industr rather than on behalf of a given projec

Issues needing attention

Eastman: I took leave from Carnegie-Mellon University and formed a computer-aided design company, believing CAD can make a contribution to the construction industry. But different design organizations are involved in the construction of any one project, and as a result, there is widely dispersed responsibility.

This fragmentation results in very poor utilization of design information. Vertical integration is difficult. There is one set of drawings that is produced for design and another set of drawings that is produced for the manufacturer—that is, the contractor.

Much of computer-aided design in the manufacturing industry today is not producing drawings at all. A drawing is necessary as a legal document in construction, both a legal contract and a communication tool.

Masters: Let's examine the problem of communicating with CAD. There isn't a universal language. I am working with 20 or 30 different architectural firms at one time, and 20 different structural firms, and 30 different owners at the same time—with varying pieces of equipment. If I can't sit down at a terminal and access data banks easily and rapidly, that $400,000 or $500,000 piece of equipment is to me a piece of garbage.

Geissler: Architects and engineers want standards. The systems houses that make the devices don't want standards now. They look upon standards as thwarting advances in technology and opening the market to competitors.

Eastman: The issue of standards is real, but for $25,000 there are software groups that will build an interface between any two different CAD systems. It simply is not an overwhelming task to accomplish.

Zack: For communication standards in the manufacturing environment, there is a driver: General Motors. Its MAP protocol enables any system to interface with any other system through a network. I don't know where in the construction industry there is anyone who has the clout that it takes to enforce and motivate that kind of system, but the system is there.

Sangrey: There are misconceptions about what's going on in construction automation in the U.S. I can assure you that Germans, Swedes, Finns, Norwegians and especially the Japanese feel there are real advantages in the technology in the U.S. We are much better in our handling of the computer in practical systems than the Japanese or anyone else. We are much better in the use of sensors than many others. But we are not nearly as good at the integration of those technologies into the construction process.

We really must focus on our comparative advantages and build from there to become more competitive. It is possible to build robotic or automated construction-related machines, whether they are fixed in a building or they wander around a construction site. We can build cost-effective machines to do a lot of the work that people are doing. The marketplace, however, does not seem to be receptive, though it's very clearly cost-effective technology right now.

Zack: One thing we in the business o manufacturing of products have learne is that the Japanese did not gain th competitive edge in product manufacturing through new technology. The gained that edge through the elimination of waste in their processes. W need to engineer the waste out of ou systems. We call it design fo manufacturability.

Bertino: We are currently working o a multimillion-dollar construction project. If you add up the man-hours of th 25 design professionals who produc the design, the shop drawings (we estimate 40,000 to 50,000 sheets), thos man-hours exceed the man-hours w anticipate onsite for construction. Something is wrong with the construction industry when the paperwork outweigh the installation labor.

Delbridge: I couldn't agree more. W have a tremendous problem. We hav been wrestling with the CAD/CAM problem in the Corps for quite some tim We are about to go out on a major bu As we have gone through the evaluatio process, we have tried to come up wi the most adaptable system—somethin easily interfaced. But in this free an open society of ours, it's hard. We can exclude the guy that still wants to use pounds of paper.

Wright: What might we learn fro the technology of the smart house?

MacFayden: The NAHB smart hous project started because homebuilder are encountering the requirement t wire for security, telephones, cable TV and ending up with seven wiring sy tems and five subcontractors. W brought in one of the national laborato

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Regional Manager, L.K. Comstock & Co., electrical contractors

James T. O'Connor
Construction Industry Institute, University of Texas

Charles E. Peck
Chairman and CEO, Ryland Group Inc., homebuilders

Kenneth M. Reinschmidt
Vice President, Stone & Webster Engineering Corp.

ries, Oak Ridge Labs, and ended up with an integrated cable system for energy, communications and very precise control.

To get it done we had to involve 40 major manufacturers. We said we would only share information with three competitors in each area—three that can do cabling, three that do washing machines, three that do telephones—and we ended up with 40 heavy hitters. The project is about a $200-million development effort in which we have changed the National Electrical Code. But it is not an open system. The manufacturers who chose not to participate won't be able to for four years. Then it will become an open system.

Geisler: Smart house problems are applicable to the movement toward intelligent buildings. In the past a person in the construction industry could build a building with a minimal amount of interface with the person who actually made devices—HVAC systems, computer systems, telecommunications systems. But the way they make them and the way they interact becomes very important in the intelligent building.

The motivation for the commercial intelligent building movement, as with the smart house project, is to differentiate a new class of building.

MacFayden: The organizational problems of doing anything in the industry are well represented by both the smart house and intelligent buildings. Trying to change anything brings you to the central issue, the process of change itself, and our industry is intractable. We need means to test and verify new technologies.

Ehrenkrantz: We have a tradition of providing appropriate test beds for new ideas. There was a time when HUD for experimental housing, the VA for hospitals and other agencies organized test beds for introducing new ideas. That no longer exists. The industry designs buildings as prototypes. And so, if we don't work with traditional products that we know from a 20-year history, we have some really grave questions about the use of those products.

Whether one thinks Operation Breakthrough was a success or failure, the Bureau of Standards probably did thousands of tests to verify that different products would perform as they were supposed to. There have been opportunities in the past to make that bridge between initial projects and the general use of products in the marketplace. We need more help in that area.

Fox: EPCOT stood for Experimental Prototype Community of Tomorrow, and the original Disney notion there in Florida was a community where people would live and work, a community into which you could plug new products, new floor plans, new buildings, to see how they worked. We have EPCOT, but it's not that experimental city.

Fagerlund: I look at our industry as a test bed. I look at every project I work on as a test bed.

Fox: One of the most notable advances in construction in some years in the U.S. is being demonstrated now by the Corps of Engineers and the Bureau of Reclamation. They have found that the simplicity of roller-compacted concrete can save a great percentage of the cost of building a dam. They have provided the demonstration projects.

Valentine: At GM we feel we're going to have to establish test beds for new building materials for auto plants. Working with manufacturers, we can install new products and try them to make certain that they are relatively proven before we commit ourselves to a major installation in a production facility. We have done this successfully on a wall panel that would be used for an industrial facility.

Stephan: We can't afford in the future to wait 15 years to apply products developed and already in use in Japan or Germany. We have the incentive, the profit motive. We need to research ways to speed up the process.

Ehrenkrantz: Encouraging various institutions to do more and better research and development has to go hand in hand with creating an environment that is hospitable to the results you are trying to foster.

Geisler: If we're going to have innovation in construction, we have to address education of the market, including the vendors, people who produce products, as well as the regulatory and political people.

Reinschmidt: The industry doesn't do research. It's not in the industry's interest; there are not substantial incentives for doing research. Recent studies in the Wharton School at the University of Pennsylvania identified some of the factors that discourage investment in R&D. The factors characterize the construction industry to a T. A large industry that is very competitive internally will not invest in R&D; one that is extremely fragmented will not invest in R&D. If there is no substitute for the product or service, you will not do R&D. There is no real substitute for construction—unless foreign competition becomes that substitute.

O'Connor: Using 1984 numbers as a percent of sales, the pharmaceutical industry spent about 7% on research, the aerospace and automotive industries spent about 4%. The Japanese construction industry spent about 3% and the U.S. construction industry about 0.01%.

That compares with the amount of research on razor blades in that year.

Kringold: In education, we're interested in research and in establishing relationships with the primary research organizations to be sure that in our formal training we are at the state of the art. We are also interested in the education of building researchers, a commodity in short supply.

We have not been able to find in the construction industry the kind of relationship that exists in other industries, which have over the long term had rela-

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Dean of Engineering at RPI,
[illegible] civil engineering

Dean E. Stephan
Executive Vice-President with
contractor Charles Pankow Inc.

Robert A. Valentine
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Engineering, Construction

LeRoy M. Zook
Manager, facility and process
engineering, Deere & Co.

tionships with universities and have established consortia to support research. The Construction Industry Institute at the University of Texas is a start in that direction, but it's only a start.

The National Research Council's Building Research Board has initiated a study supported largely by the National Academy of Engineering to determine how the structure of the construction industry in Japan, France and Sweden makes those countries particularly competitive, to look at all aspects of competitiveness and not just our subject of needed technologies.

Suggestions for action

Cardwell: The ability to implement information systems technology may very well be the key to construction's ability to continue to grow and compete.

Hill: In the early 1980s, some in the manufacturing field started to develop IGES, the Initial Graphics Exchange Specification. In the last two or three years, there have been efforts to address the architectural-engineering-construction application—to develop standards so graphical data—plans and drawings—can be transferred from one party to another.

MacFaydan: If I understood Gen. Delbridge correctly, the government is not going to use its purchasing power to standardize CAD/CAM systems.

I think there is a point in time at which you decide that the benefits of standardizing are such that you can use the purchasing power of GM and use MAP. A lot of industries don't standardize on time. But if you standardize too early, you impede development.

Cardwell: The current explosion of technology is the very thing that would keep you from establishing a standard for the federal government or anybody else.

Reinschmidt: Computers are revolutionizing a lot of industries. They may revolutionize the construction industry, or they may bury it.

Unfortunately I do not believe that the construction industry is going to band together on this problem any more than the farmers banded together to advance agriculture. It took the Department of Agriculture. We need a focal point. It does not exist now and I think it ought to.

Peck: There has been a lot of technological progress from all of us doing our thing better, sticking our necks out, taking risks, responding to an urge to do new and different and innovative things.

We ought to strongly support the institutions that are in place to bring research forward. That certainly starts with the Center for Building Technology, but it includes all of the consensus and committee organizations that support the construction industry. Then I believe that we each need to be more assertive, and in the American entrepreneurial tradition, let's do our own research.

Valentine: General Motors does not spend a lot of money on R&D in the construction area. It's my particular challenge to see that we increase that involvement, not duplicating ongoing efforts but trying to build on them.

Carlisle: Our International Union of Bricklayers and Allied Craftsmen is small in relation to some of the other building trade unions, but years ago we recognized the need for more research. Some 81 of our unions collect funds to support research efforts through the collective-bargaining agreement.

We have a committee that is beginning to raise a fund of $20 million annually through the collective-bargaining process for technology, and for research.

Evans: The way to get technology is to spend money. Congress should increase research money spent, whether it's at a university, in the national laboratories or for demonstration projects.

Jortberg: These are terrible times in Washington, or any other place, to be increasing the funding of programs that have long-term payoffs.

At the risk of showing some bias, I think we have to be careful not to demotivate or slow down the ongoing activities of the Contruction Industry Institute. It is perhaps the first time that there has been a free and open association of owners, contractors (absent the homebuilders), the government and the academic community. The 55 member companies and the 15 or 20 academic institutions involved are beginning to make a major contribution.

In pursuing government help we don't want to discourage private organizational help.

Delbridge: CII is funded by private industry, but at the same time it makes us agencies part and parcel of those things on the R&D of construction management. We can and will participate in demonstration projects. Some of the federal agencies can do it a little more easily through CII.

The federal government's processes have traditionally been highly structured, bureaucratic. But right now change can take place more easily than any time I have seen.

Sangrey: The primary issue we're talking about is productivity. Other countries are taking a much more strategic look at construction productivity, and there are things that we can do in this country of like type.

We will continue to have evolutionary improvements in productivity, but we also ought to look at what a revolutionary environment would produce for us. Many of the kinds of changes that we want to produce are only going to come about in a somewhat more revolutionary environment.

We have to have some major demonstration projects where, with continuity of user to supplier to designer, you can really demonstrate that there is the potential for significant improvement in construction.

We need to encourage the only organization that has that integration of user responsibility, the federal government, to sponsor the kind of long-term and potentially revolutionary development of construction productivity techniques. A lead national laboratory is necessary in this country. Many countries around the world have them.

We should also encourage the National Academy of Engineering, through the National Research Council, to take responsibility for national leadership and coordination of the construction productivity issue.

Fagerlund: There is a school of thought that says people don't change unless there is some kind of significant emotional event. Look back on the '70s—tremendous inflation, coupled with stiff energy prices. Those were significant emotional events for us as a society, and we did things to respond to them.

Computerization of our industry, liability—right now those are two very significant emotional events that may or may not be powerful enough to drive us together to deal with the collective and interactive aspects of those problems. We started out saying that there might be another wave of some kind of competition for us, Japanese coming over here and running us all out of business. If that in fact happens, I am sure that will be another significant emotional event.

This is esoteric, but I think it's also realistic. We need some forces on us to bring us together as a construction industry, not as architects and bricklayers and 17 other elements, each with our own agendas. The agenda that's missing is the collective agenda. That is the single most important bottom line in this whole thing. ■

Edited by Arthur Fox

Big market has big problem

Electric and gas utilities, telephone companies and local governments plan to spend about $90 billion more in this century to computerize and integrate the management of infrastructure, according to a recent report, but they may have trouble finding money to pay for their conversions, says one of the people who prepared the report.

"The biggest single problem facing those automating infrastructure management is the cost of data conversion," says Jerry W. Robinson, president of The Automation Group, Rosemont, Ill. The group is part of a triumvirate of consultants that prepared the *1986 Intelligent Infrastructure Market Report*.

"Costs will be coming down, however, as the cost of the required hardware and software comes down," says Robinson. But the cost of labor to input the data will continue to rise some in the U.S., he predicts. Relief may come from companies, such as GTE's Codetel subsidiary in the Dominican Republic, that provide data conversion services using lower labor rates, he says.

The report, available for $1,990, summarizes questionnaire responses and interviews from more than 300 targeted gas and electric utilities, telephone companies and local governments throughout the U.S. It describes each business sector and its particular requirements for automated infrastructure management. It also discusses the problems facing those sectors, including the inadequacies of nonintegrated systems, the retirement of key personnel and demands for containing costs.

The report identifies trends in technology, such as automated digitizing, the storage of raster images, optical disk storage, communications and artificial intelligence.

Robinson says that utilities and other entities that perform infrastructure management will make the decisions about which system will be used, not their design consultants. "When an end-user organization buys a system, the people who service it will buy the same system," he says. The $90-billion figure is in year 2000 dollars. ■

Design school pans software

Researchers at Harvard University are blasting most commercial microcomputer design software as ill-suited for students, and confusing even for many professionals.

After studying 65 programs, researchers rated only 12 as excellent for teaching. Sixteen were practically useless and the rest were marginally useful or useful only if modified, they say.

The 65 were selected from 600 programs for the two-year study, done by a team of students and faculty at the Graduate School of Design. The school names the programs in written reports, which sell for $4, $6 and $8.

Student training hampered by weak commercial programs.

Confusing. "We found any number of programs that—by virtue of the way they are constructed in a programming sense, the way data is input, the way files are manipulated—would confuse anybody," says Daniel L. Schodek. Schodek is the director of both the school's Laboratory for Computer Graphics and Spatial Analysis and the study team. "Even a professional would find it difficult to use some without endless calls to the vendors."

There are 19 reports in all. Ten of them analyze the educational value of specific programs for applications studied in schools of architecture, landscape architecture and urban planning. These include design representation, drafting, structural analysis, environmental control systems (thermal, lighting and acoustics), site engineering (earthworks and drainage), real estate analysis, geography and transportation. Other reports discuss microcomputer needs of design schools and methods of evaluating teaching software. There is also a survey of design school curricula and user-interface criteria in design education.

Programs differ widely, making it expensive and time-consuming to install them for student use, say the researchers. Vendor sales literature offers little help in assessing capability, they add.

Complicated. Many programs were judged to have complicated input-output requirements and poor documentation and tutorials. Others lacked graphics to supplement alphanumeric data, which made design comparisons more difficult.

Therefore, many programs were found to be suitable only for advanced courses. Running programs through generic problems, "not the canned problems provided by the vendors," showed that software with a narrow focus is easier to adapt to classroom use than comprehensive packages that purport to handle several situations.

Three-dimensional modeling programs are difficult to use, site engineering packages do not integrate drainage data with roadway layout schemes, real estate programs lack floor-area ratio and other important planning variables, and software for transportation finance analysis is scarce, the team concluded. ■

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August 14, 1986

TO: DISTRIBUTION

The construction industry is ready for high performance plastics and GE!

Also, the industry will generate significant market opportunities in other market segments., i.e., computers, telecommunications and electronics!

If you want to know why, please read the attached articles.

Eric

Eric Balinski, Specialist
Building and Construction Program

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Mr. BALINSKI. What we recognized was that there are real issues and what we thought in addition to providing our formal presentation, we'd talk about was GE Plastics' role. GE Plastics has recognized these as real challenges to our industry and we wanted to do something about them.

We've developed a long-term research and development perspective on the construction industry. We focus it on a program called "Living Environments". "Living Environments" is really a project to take a look at some of the issues and we've done this by assembling a team of designers, engineers and technologists to start to understand what the issues are really about.

One of the unique perspectives to the research is that we've done this with the participation of over 40 other companies. We've heard already from some of the other panel speakers that I think too often some of the research doesn't necessarily have an industry-driven or marketplace focus. We thought that was a particularly interesting point about when we looked at the construction industry and some of the challenges facing it.

Do we have all the answers to the construction industry through the "Living Environments" program? I don't think so. Can we do it alone? I don't believe we can do that either by ourselves. But what we do recognize is that there are substantial challenges facing us and what we wanted to highlight just very briefly is our commitment to this industry and the need for industry, as well as government, to do something about it.

I said we've provided written testimony which talks about the "Living Environments" project in some detail, describing whats been done. What I'd like to briefly do now is just make some of our recommendations to this committee.

What we do feel is we need your support. We need you to recognize—industry needs you to recognize really the importances of these challenges facing the construction industry. I think Jesse Pfeiffer earlier, when he spoke, mentioned that government should be a catalyst to help the industry move along. That is a word we use within the "Living Environments" program over the past three years, provide a catalyst to industry to bring about some of the changes necessary.

The other thing we feel very strongly about is more of the research that's being done needs to be tied to a commercial reality of the challenges facing the construction industry. Again, the CARP program is a good example where that's starting to happen. I know DOE is starting to take some of those initiatives.

I think one of the key things that we've learned over the past three years, is, the knowledge that's gained from research is not the economic power. Economic power will come from the implementation of the market research. That ultimately will make us a stronger industry and a stronger nation. What we also want to do is encourage much more cooperative effort within industries and between industries, as well as between industry and government. Again, I think you've heard some things already this morning that talk about that and we applaud those efforts. We think those need to continue and to—again, government can play the role as a catalyst to encourage those things.

Another one of the challenges that continues to face particularly new technology within the construction industry are a number of the barriers, both codes and regulations. From a longer-term perspective, we'd like this subcommittee to take a look at really these challenges and start to plan on how, as technology is introduced, how we can better bring this technology into the commercial marketplace.

To just quickly summarize, you wondered in your opening statement, Mr. Chairman, does government have enough of a role as a partner? We feel that role can be strengthened! We welcome that opportunity to help this subcommittee provide any answers today, as well as into the future.

With that, I'd be happy to answer any questions. And also, take this opportunity to show a video. I was intending to provide a tape after the proceeding for your own viewing pleasure and your subcommittee's members' pleasure, a video describing in a little bit more detail our "Living Environments" program. So if you're interested, I'd be happy to hook it up.

Mr. **Walgren.** Sure, we'd like to see it. If you have it with you, that would be good.

Mr. **Balinski.** Okay.

[A videotape presentation shown.]

[The prepared statement of Mr. Balinski follows:]

A Foundation for Change in the Construction Market: GE Plastics' LIVING ENVIRONMENTS Project

By Eric Balinski
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Presented to the Science, Research, and Technology
Subcommittee of the Committee on Science, Space, and
Technology

U.S. House of Representatives

September 12, 1989

A Foundation for Change in the Construction Market: GE Plastics' LIVING ENVIRONMENTS Project

Several years ago, when GE Plastics began to consider the long range opportunities for its expanding plastic technology, we focused upon two factors which we considered essential to our ability to significantly expand our markets into the next century.

The first was the realization that as a potential marketplace, the construction industry represents our greatest opportunity as the largest user of materials, and that the use of our materials in the market was virtually insignificant.

This market profile combined with the increasing disparity between the growth of median income and home prices, the well-documented labor intensity of home building, and the fact that construction methods had changed little in the past fifty years......made it a market ready for fundamental change. This is a change that would be well suited to take advantage of the inherent benefits of plastics from the standpoint of both performance and fabrication.

The second major factor that challenged us was the mounting issue of solid plastic waste and the realization that as the use of our materials continues to grow in today's expanding plastic markets such as automotive, telecommunications and packaging, GE Plastics as the originator of these high performance materials would be held at least in part responsible for developing solutions for dealing with the increasing volumes of this waste material in the coming decades.

The housing crisis and solid waste disposal: these two seemingly disparate social and economic concerns became the basis for GE Plastics launching an ambitious research and development project to engineer realistic solutions for the future growth of our business. Inherent in our undertaking was the recognition, that if we were able to develop a comprehensive materials strategy that provided solutions to both social concerns, we would, in fact, transform potential problems into long-term opportunities.

After a year of preliminary research with major leaders in industries associated with housing.......construction, appliance, electrical, and lighting to name a few......and on-going development with our own technologists, we realized that our twin goals of increased penetration into the construction market and a recycle program were compatible, and the LIVING ENVIRONMENTS project was born.

Today we might describe LIVING ENVIRONMENTS as a multi-year research and development project designed to explore opportunities for GE Plastics technology in the construction marketplace as an alternative to traditional materials. It's a project that represents over three years of research and involves more than forty different partner companies in the U.S., Europe, and Japan.

From the broadest perspective GE Plastics sees this project functioning on several levels as:

-a catalyst to help drive change.

-an ongoing living laboratory as the nucleus and focal point for creative systems and application development.

-a source of in-depth knowledge that will direct future materials development to meet emerging construction needs.

-a means of developing relationships with people and companies to translate new materials technology into commercially viable products as quickly as possible.

A secondary business objective was to develop new materials that augmented and broadened our product line without directly competing with our established products. As engineering materials, GE Plastics' products are not the so-called commodity materials used in disposable packaging and low-end applications but are high-end, high performance materials used in everything from car bumpers to computer housings.

As engineering thermoplastic resins, these materials are easily reground and ready for reuse, losing only a fraction of their performance after a single use, making them ideal candidates for some form of recycling or regeneration.

Therefore, we saw our real opportunity in the creation of entirely new technologies, which in turn will create a new market segment -- a market segment in which our recycled, or regenerated materials could compete with traditional lower-cost materials such as wood, metal, and glass. We also had to develop these new technologies for long-term uses such as building and construction products to avoid the issue of recycle again after a second use of our materials.

It must be underscored that our goal is to provide a on-going laboratory in which companies interested in exploring new alternatives for their products can interface with our developmental materials technology.

There is no question that in the US there is a need to change the US residential construction industry. Already in Japan, Scandinavia, and Europe home construction based on new materials and fabrication technologies is well established and accepted. Importation of these technologies has already begun and there is every indication that without domestic alternatives being developed these companies will make in-roads into the US market.

To date, in the LIVING ENVIRONMENTS project, GE Plastics has spent three years and six million dollars -- and that is because we saw the opportunity. But there is another reason. It is our realization that industries cannot remain static, especially when a crisis is reached as we now see in housing. A fact clearly illustrated by the new profile adopted over the past two decades by the automotive and electronics industries. Further, there is the economic reality that if we did not pursue this course of inquiry another company would......and probably in a country mentioned above where these housing issues came to a head after World War II.

However, we have an advantage over all of them. Our advantage is that GE Plastics is the leading innovator in new plastics technology, and we are pressing this advantage and taking the lead in both developing and commercializing this technology in all industries associated with home building.

In a month we will open a 3,000 square-foot concept house that showcases our success thus far and provides a forum to take us further into the exploration of new materials technologies for this market. In that concept house you will see the efforts of over forty partnerships with some of the top names in the industries that serve the residential housing market.

Among the developmental products on display are a full spectrum of short, medium and long-term concepts, ranging from recently commercialized products such as a new exterior siding to long-range conceptual exploration of interior wall panel systems for a industrialized factory-built housing system.

The house also illustrates our recycle materials strategy. For example, the sidewalk leading to the front door of Living Environments is made from an "engineering concrete" developed by GE Plastics and Master Builders, a leading concrete additive company. Almost 60% of the mix is reground engineering plastic.

There is also a new technology called Radlite -- a pressed plastic sheet that is a composite of engineering plastic and glass fibers. It's a unique material technology that combines the structural composition of composites with the fabrication ease of thermoplastics. It was, interestingly enough, developed in a joint venture with a paper company. This technology has such versatility it has allowed us to develop composites using numerous types of recycled plastics.

Given the material's structural strength and durability, it could be used in interior wall systems or perhaps flooring...we're still exploring the options....but we recognize it as offering some unique advantages which has the potential for broad application in the right hands...and that is precisely where the expertise of the partnership companies comes in.

And the beauty is, even if this material falls short of our expectations, there are many other material technologies under development by our technologists. We're looking at everything from new chemistries, to new fabrication techniques, we're even examining new formulations that consist of plastics and conventional materials such as glass, gypsum and even wood fiber. It is a research laboratory approach in which new ideas emerge daily as we work in partnership with many of the major suppliers in the construction industry. It's really the strength of the LIVING ENVIRONMENTS program. We develop the materials and together with our partners we shape ideas into commercially viable products.

In every aspect of applying our emerging materials technology to this marketplace, we are attempting to translate the unique strengths of plastics into cost-effective solutions that replace traditional construction methods and materials. And in the process we look at not only replacing pre-existing products, but we have the ability to explore entirely new concepts in products made possible by the performance range and versatility of plastics.

-- like roofing systems that provide structural support, protection and heat water.....

-- like pre-fabricated wall systems that already have electrical access, and heating duct work integrated into the structure.

These are some of the means we are using to explore and develop new opportunities in the housing market. In the process we will explore virtually every avenue where plastic technology can be applied, knowing full well that plastics will not be the answer to the problem, but a portion of the solution.

We are not developing a fully integrated plan for pre-fabricated low-cost housing, nor can we offer the absolute solution for solving the affordability issue of US housing. What we are offering is a new set of ideas, concepts and directions all of which may someday find themselves used in innovative solutions for the housing requirements of the future.

In the broader context of the housing issue, the real strength of the LIVING ENVIRONMENTS project may not be so much the ideas that have initially flowed from the program, as the process itself. The process of merging experimental technology with the expertise of diverse industries and the working together in partnership to find solutions. It is industry teaming up with industry and sharing expertise in an effort to develop new products that will be realistic, economically viable, and beneficial to all participants -- and perhaps ultimately to our society as a whole.

GE Plastics' role in this endeavor is to be a catalyst and active participant in a change destined to take place in the construction industry. We will do it by providing both a forum for discussion of new ideas and by supplying some of the basic technology for new direction in that industry.

As for the role of government in our efforts we see only the need for understanding and a cooperative attitude in dealing with the results of our research and development. A cooperation that will be tested some time in the future, when a partner company comes before you and asks that some part of the massive infrastructure of codes and laws in the construction industry be revisited in light of new technology -- that is when governmental support and action will be required.

There is no question that in the home building industry a vacuum of leadership exists...and one of the primary reasons for this is that a house represents so many distinct industries, and few companies cut across the lines. Thus, there is very little coordinated effort to bring new technology to the home building marketplace and although new fabrication technology such as factory built homes and newer systems developments mentioned earlier will not solve the problem, they certainly will be part of the solution.

The fragmentation of the market is no doubt problematic, although clearly, as we have seen given the overwhelming response of the associated industries to LIVING ENVIRONMENTS -- industries like the electrical appliance and lighting industries -- they are eager to move forward. We see our role as providing a critical piece of the equation to help them move forward and in doing so assure that GE Plastics will be a major player in a market destined for change.

Mr. WALGREN. Well, okay. Thank you very much for that.

Can you give any more descriptiveness to the idea of systems and—that Mr. Eberhard talked about and—and this five-year suggestion of yours, Mr. Killen?

From the outside, it's a little hard to know what we really mean by—by systems or what-not, or what is meant by that—that concept?

Mr. Eberhard?

Mr. EBERHARD. I think there's some easy models if we look at the larger than buildings. If we look at cities and we have sewer and water systems. We have electrical distribution systems. We have communications systems. We have transportation systems. Those systems are made up of components like automobiles and roads and stoplights for the transportation system, which I gather didn't work too well in Washington this morning.

Mr. WALGREN. Yeah.

Mr. EBERHARD. But systems improvements could come in any one of the components, but the difference in what has happened historically in the building industry and what I said happened traditionally in the telephone industry is that every improvement, whether it was on an instrument telephone, whether it was on a communications equipment, whether it was on a way of installing the lines in the field, were always looked at a systems problem. How is this going to improve the telephone system as a communications device?

In the building field, because we are fragmented, because we look at, particularly in the private sector, tend to look at individual components as something we want to improve, the system's view of the opportunity gets lost. That's one of the roles which I think is still available for the Federal Government to make some inroads into and Tim's notion of a five-year program seems to me could fit that one as well.

Mr. KILLEN. Yes, when I think of systems—let's take a very functional system like placing concrete at a job site. That's a system that includes a material. It includes a design. It includes machinery and possibly automated machinery to help place that concrete and then instrumentation, perhaps, and controls.

There's a lot of elements to how you go about designing and placing concrete and then checking that it's acceptable. So when I talk about a construction systems and how we might improve those systems, I'm talking about from the design all the way through to the implementation at the job site, looking at it not as individual components and pieces and robots, but looking at it as a whole problem.

Mr. WALGREN. You're saying that these kinds of things can be taken on over five years and, Mr. Eberhard had mentioned the Advanced Technology Foundation as a—something that's in the area. Do you have other suggestions as to how those kinds of problems would—would be organized or placed?

We have the centers, the two centers that you mentioned. What were they again? Austin—

Mr. KILLEN. Yes. The two centers I mentioned were the Construction Industry Institute in Austin, Texas, and then at Stanford is the Center for Integrated Facilities Engineering. We call it CIFE.

And they're both very active and aggressive organizations of academics and private industry to outline research needs and perform research.

Unfortunately, a lot of that research today is study nature and what we are going to need to do is develop products for use at our job sites and today there's just not enough of that area of research. I'm not talking basic research here; I'm talking about using off-the-shelf modules and pieces that exist in technology but you put them together functionally to make an operating machine, for example.

Mr. WALGREN. We have in the National Science Foundation the various centers for engineering and things like that focused on a given problem, and certainly the Center for Building Technology is a natural if it had any money, I guess. If it had any support.

Mr. EBERHARD. It's not broken, Mr. Walgren. It just would like to have more money.

Mr. WALGREN. I wonder—I guess part of it is how you get proposals focused and made from the private sector framed around a problem like cement construction, I guess, or handling of cement, and then—and then having a center that has some of the—of the technological skills to try to solve it on a systemwide basis or with a systems type of approach.

I wonder how big a center like that would be? When we say they're not broke, that's true, they're not broke, but they only have about $4 million of government money, direct government money, and there's limits to what you can do with that, how big a project you can undertake.

Well, the raising of the money will have to, I guess, be for another day and even the definition of the projects is another area of interest and it will be interesting to see how those suggestions are made to the Center for Building Technology and whether, if you were able to do a good job with the suggestions that are made, whether you would advance the cause of construction innovation substantially. Perhaps you would.

Well, I want to thank you for being a resource to the committee and for the part you play in the discussion of these issues in public forums and I'm sure that a number of the industry forums will be able to look at the record we have here and see kernels in it that they would like to develop and pursue as well.

So we look forward to where this area can go. It's a hard area for the Congress to address because it's—we, in a sense, don't have a direct crisis that drives us and that's usually what drives the Congress but from a science and technology standpoint, we hope that we can keep people interested enough in it that when the possibilities of making real contributions are there, the people and their resources necessary to make them happen will be there as well.

Well, with that, we'll close the hearing and I want to express our appreciation to you. Thanks very much.

Mr. EBERHARD. Thank you.

Mr. KILLEN. Thank you.

[Whereupon, at 11:50 a.m., the subcommittee was adjourned, to reconvene subject to the call of the Chair.]

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